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FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
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INDUSTRIAL ENGINEERING
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June 1977
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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Proceedings of the REAPS Technical Symposium

June 21 - 22, 1977
New Orleans, Louisiana

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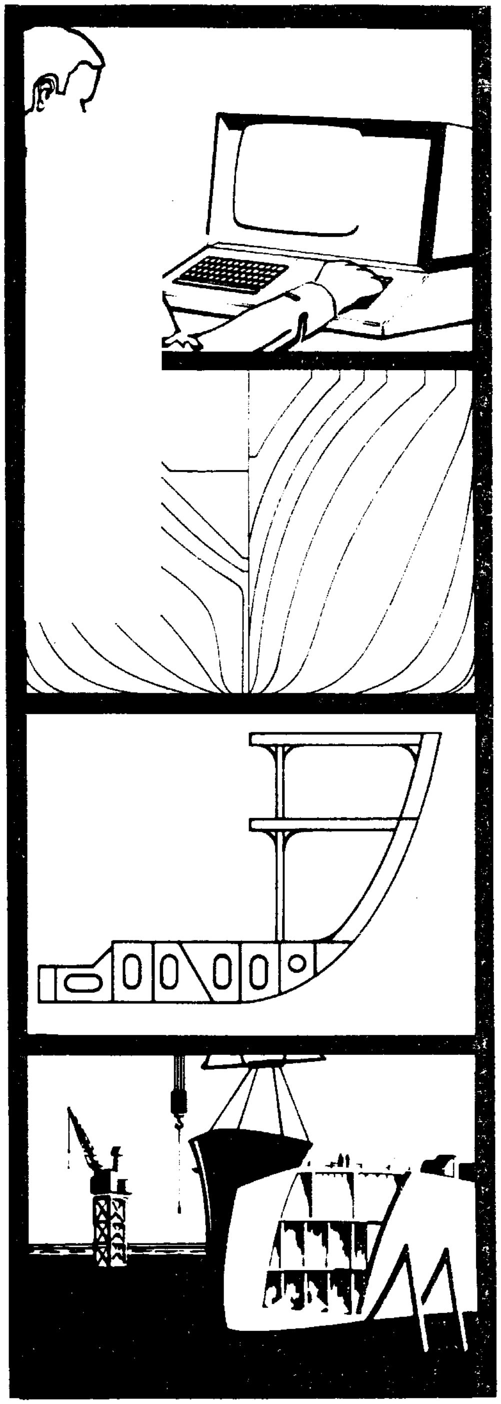

R ESEARCH
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FOR
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IN
S HIPBUILDING

Proceedings of the
REAPS Technical Symposium
June 21-22, 1977
New Orleans, Louisiana

IITRI

Proceedings of the

REAPS Technical Symposium [4th annual]

June 21-22, 1977

New Orleans, Louisiana

Research and Engineering for Automation and Productivity in shipbuilding

IIT RESEARCH INSTITUTE
10 WEST 35 STREET
CHICAGO, ILLINOIS 60616

The 1978 REAPS Technical Symposium will be held in June in St. Louis, Missouri.

Proceedings of the 1974, 1975 and 1976 REAPS Technical Symposia are available from the REAPS Librarian, IIT Research Institute, 10 West 35th Street, Chicago, Illinois, 60616. To order specify year, catalog number and medium desired:

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PREFACE

The REAPS program is a shipbuilding industry/government effort aimed at improving shipyard productivity. The cooperative spirit characterizing the development and implementation of computer and manufacturing aids for shipbuilding is a key factor in the program's continual success.

The 1977 REAPS Technical Symposium occurred June 21 and 22 in New Orleans, Louisiana. It provided a forum for presentation of current advances in shipbuilding techniques and technologies. That the industry found it a valuable information exchange is evidenced by the attendance of 162 representatives from 61 yards and support groups located throughout the world.

Following the Symposium on June 23, Avondale Shipyards, Inc., hosted a walking tour of their facilities. The four-hour tour, attended by over 50 observers, included the: data processing department, N/C mold loft (graphic demonstration), machine shop (N/C burning machines), pipe shop, dry dock, T-beam fabrication shop, plate shop (N/C burning machines), and panel line. Special thanks are extended to Avondale for this most interesting and informative presentation.

The Proceedings of the 1977 REAPS Technical Symposium contain most of the papers presented at the meeting. The Agenda in Appendix A lists topics and speakers, while Appendix B identifies Symposium attendees.

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Douglas J. Martin
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Chicago, Illinois

Mr. Martin is Group Leader for shipbuilding technology at IIT Research Institute. He is responsible for managing the REAPS program as well as other projects in: computer aids to shipbuilding, computer aided design and shipyard manufacturing technology.

His previous experience includes the development of computer graphics systems for ship design and lofting applications, software for marine transportation system economic analysis, and a software system for real time model test data acquisition and analysis.

Mr. Martin has a degree in Naval Architecture from the University of Michigan.

INTRODUCTION

The origins of the REAPS Program and its evolution since 1974 have been reported upon quite thoroughly in this forum in the past, so I will not retrace that ground here. For the benefit of those who may not be familiar with REAPS, -- its objectives and workings -- however, let me briefly review these in their current context.

THE PROGRAM

REAPS today is a shipbuilding industry/government (MarAd) cooperative development program aimed at improving shipyard productivity through the development and implementation of computer and manufacturing aids for shipbuilding. The program is organized as an element of The National Shipbuilding Research Program, which is administered by the Ship Production Committee of the Society of Naval Architects and Marine Engineers.

The program itself is organized as follows. The most important group within the program is the REAPS Representatives. These are the participating shipyard personnel from production management, the loft and design who make the program work. At meetings of the Representatives, MarAd and the Program Manager (held four to five times yearly), the Representatives jointly identify problem areas of mutual concern, discuss alternative solution strategies and formulate development project descriptions and implementation plans. An interested member may then formulate a project proposal which is then again critically reviewed by the group before it is endorsed as a recommended project for submission to MarAd. An integral part of each such proposal is a

forecast of the savings or benefits to be obtained as a result of the development, usually on a per ship basis.

If the proposal is accepted by MarAd, a cost sharing contract is issued to the yard. Under this arrangement, MarAd pays the yard's direct costs on the project, while the yard itself financially participates in the project by forgoing its overhead and profit.

Once a project is initiated, a Project Advisory Group is formed consisting of member yard personnel and, on occasion, personnel from non-member yards, who will have direct responsibility for the use of or performance of the development once installed in their yard.

As the name implies, the function of these groups is to advise the shipyard contractor on technical and operational considerations and capabilities concerning the development to ensure that the delivered product meets industry-wide requirements, not just those of the yard developer.

During development, the Representatives are continually apprised of the project's progress and any problems that may arise. The objective here is to be alert to any "mid-course corrections" that may be either necessary or desirable in order to insure that development's ultimate implementation success.

The final, and most important, phase of this process is implementation~ Depending on the nature of the development itself, this step may consist of simply using the prototype in production in the yard in which it was developed and providing workshops and technical information and specifications to the industry. This might-be the case for a computer program. For a prototype piece of manufacturing hardware, however, the developer might solicit machine builders

to produce the piece of gear, providing all necessary design drawings, specifications, etc. It is one of the Program Manager's jobs to ensure that these developments receive industry-wide exposure and that the means of acquiring and using them are provided.

The Program Manager (IITRI) provides a number of other services in support of this basic development process including:

- Providing the Representatives with reports on technology from allied industries of potential use in the yard.
- Providing a number of technical information services (including this conference) in order to keep the Representatives (and the industry at large) abreast of new developments.
- Chairing and handling the logistics and details of Advisory Group meetings and Representatives meetings.
- Carrying out, or managing, development projects as directed by the Representatives.
- Providing manufacturing and computer related technical support to the member yards.

PROGRESS

The Program, as described in the foregoing, has been operating since last August, although many of the development projects currently underway were begun earlier. One way of gauging the progress of the program to date is to examine the projects currently underway and those about to begin.

- Pipe Detailing System

The function of this system, being developed by Newport News Shipbuilding, is to reduce pipe detailing and fabrication labor costs. The system itself contains a minicomputer system and up to four user stations, each consisting of a digitizer, a CRT graphic display, a keyboard, and an alphanumeric display for prompting messages. The users of the system will be able to digitize details from composites or arrangement drawings approximately twice as fast as the manual detailing process. The output of the system will be complete pipe shop work packages including a shop drawing, a material list and bending instructions. The system is slated for delivery in March, 1978,

- Damaged Stability Program

Bethlehem Steel Corporation's Sparrows Point yard is currently developing a comprehensive damaged stability analysis program for ship-like and arbitrary forms, such as drilling rigs and drydocks. The user will be able to specify conditions of damage and compartment geometries in a number of convenient ways and direct the program to perform any one of several damaged condition analyses. This project will be complete in September of this year.

- Hull Definition Fairing Program

The object of this project, being carried out by Newport News and a contractor, CADCOM, Inc., is to adapt the Navy-developed Hull Definition Fairing program to commercial use and assess its performance benefits over those fairing programs currently in use. The delivery of the program was made in May of this year to MarAd. After a test and evaluation period at Newport News, the program will be

delivered to the industry, along with a training workshop, in September of this year.

● Graphics and Communications Terminal

This project entailed the design and specification of a computer terminal for simultaneously processing remote job entry (RJE) Communications and N/C verification graphics on either a CRT or a drafting machine. The design and specification as well as a significant portion of the software for this system is complete. One of the REAPS yards is currently processing a procurement request for the terminal's minicomputer system and has the drafting machine in house.

● Parts Definition System

The goal of this project is to design a minicomputer-based system for. use by the loftsman in interactively defining, reviewing and editing part geometries; The system is designed to alleviate the problems faced in many lofts of loss of skilled loftsmen, the difficulty in training new loftsmen in the use of parts programming language, and long job turn-around times at some installations for batch parts programming runs.

This project is scheduled for completion in August of this year by Newport News. If the projected economics of the use of such a systern prove attractive, the development of the system will follow.

● Cold Twist Forming of Structural Shapes

The objective of this project, being carried out by IITRI's Metals Division, is to design and build tooling to perform the twisting of

shapes in a conventional hydraulic press. Conventional twisting of furnaced shapes is currently one of the most grueling and labor intensive jobs-in the yard. The use of the fixtures and dies with a hydraulic press will allow a much smaller crew to twist shapes, with up to 36 inch deep webs, much more productively.

A one-fifth scale prototype set of tooling is currently being fabricated at IITRI and will be tested to determine the feasibility of the process for different materials, the need for local line heating, etc., before fabrication of the full scale tooling,

- Steel Marking Device

The marking of steel shapes and parts with piece identification information is currently a tedious, manual process wherein hand-held character stamps are hammered into the material, leaving the character impressions. An alternative to this manual method for N/C cut parts is to use the burning machine's center punch to bang out the character patterns of the piece ID. But this method is slow, tying up the entire machine during the marking process thus reducing steel throughput. In addition it is hard on the center punch itself.

The purpose, then, of this project is to come up with a cost effective marking tool, suitable for the retrofitting of existing burning machines, which can mark alphanumeric ID information at a sufficiently high speed that the throughput of the burning machine is not noticeably degraded.

IITRI is currently investigating the costs and throughput characteristics of several devices. Among these area rotating carousel of characters and pneumatic punch (a device consisting of a set of

character wheels , and a simple, inexpensive end mill or router tool]. The device found to be most effective in terms of cost/performance will then be developed and retrofitted to an existing machine for test and evaluation.

In the near future, the following additional projects will be started:

- Sheet Metal Template Software

  The purpose of this project is to eliminate the need for manual sheet metal layout work through the development of a series of software subroutines to compute the geometry of sheet metal layout templates for most of the commonly encountered duct intersection and transition piece cases in yard sheet metalrk. It is estimated that 80% of the templates currently developed manually will be handled automatically via this software, saving in excess of .10,000 man hours per new design.

- Computer Aided Cost Estimating

  The goal of this project is to develop a rational approach to yard cost estimating which can be implemented on a computer. A computer program will be developed, which will produce a material list and associated labor content by ship module (e.g., hull, main propulsion, auxiliary machinery, etc.). This information will be organized within the framework of a particular yard's cost group system. It will be useful in negotiating a new construction contract or for playing the "what if" game with potential owners in analyzing the cost effects of varying certain preliminary design input parameters. The program is expected to reduce estimating man hours and to improve the reliability of estimates.

As I think you can see from this list of projects, the REAPS program is involved in the cooperative solution of a variety of problems spanning yard processes from preliminary design to steel fabrication. We expect this technical diversity in REAPS-sponsored projects to continue' in the future.

These projects in fact represent progress made by REAPS in many technical areas. But the REAPS program and its group of Representatives, has made progress in other equally important areas. The following is *a* list, necessarily incomplete, of some of the more important ones.

- People - As I mentioned earlier, the shipyard Representatives are the key to the program's success or failure. REAPS has succeeded in involving a group of the best technical personnel in the industry in a joint problem-solving process which has become very effective. Their expertise spans most facets of design and construction, computer technology and manufacturing technology, bringing to bear a unique set of capabilities on the various project areas.

- Communication - The establishment of open communications between yards". is crucial if common problems are to be identified and attacked cooperatively. The REAPS yard Representatives have made enormous progress in opening up the channels of communication between yards on operational and technical topics. Technical discussions between yard Representatives are now wide-ranging, informal and highly constructive. This free flow of technical experience is in reality the foundation of the program on which is constructed the solutions to individual problems identified by the group.

- Mechanics of Operation

The REAPS group has overcome most of the organizational and logistic obstacles which can act to impair the effectiveness, on a technical level, of a program like REAPS. The group has, for example, gotten used to the process of formulating and initiating development projects, and to the pro`cess of technically monitoring these projects as a group. The REAPS yards, in addition, have overcome some early difficulties in executing cost-shared contracts with the Maritime Administration, and vice-versa.

In short, the group operates fairly smoothly, allowing the vast majority of its time and energy to be expended on the solution of technical, not organizational, problems.

- Perception of Government Involvement

The perception of the government within the shipbuilding industry as being the regulator, or worse, the meddler, is a long-standing one. Whether or not this perception ever was a significant problem for REAPS is debatable. But what REAPS and, indeed, all of the operating components of the National Shipbuilding Research Program have shown is that the government can play a constructive role within the industry by provialing a positive stimulus to the shipyards to bring about the technological improvements the industry itself wants.

PROSPECTS

Based on the foregoing, I think you will agree that the prospects for success of the REAPS program in the future are excellent. The program has assembled a highly qualified group of shipyard technical personnel who have an understanding both of the problems and the technology available for use in their solution,

An informal, productive environment has been established within which these people can work to accomplish their common objectives. And finally, vehicles have been established for initiating development projects, for insuring that the developments themselves meet industry requirements, and for implementing and integrating these developments smoothly into the yards. In short, all the necessary "pieces" are there.

As necessary as these features are, however, they are not sufficient to guarantee future success. The REAPS group must continue to work to identify new opportunities for productivity improvement and to capitalize on rapidly evolving technologies in order to continue to produce cost effective solutions to productivity problems.

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N/C JUSTIFICATION IN THE SHIPYARD

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Mr. French is responsible for reducing ship production costs. This involves evaluating potential improvements, selecting the most cost effective one, preparing detailed justification for management, and insuring implementation of approved changes.

His past experience with Bath Iron Works has involved working on the MarAd Ship Producibility Research Program to reduce the cost of commercial ship construction, managing the company's energy conservation program, and justifying the N/C plate burning investment.

N/C JUSTIFICATION IN THE SHIPYARD

Changing to computer-aided lofting and N/C burning from tenth scale, as Bath Iron Works is in the process of doing now, is a traumatic experience. The fact that there are so many other yards successfully using it for the past several years is certainly some comfort, but by no means eliminates the anxiety. This change in process has the potential for changing more people's jobs than, any other change at BIW in many, many years. This realization has been one factor that has caused the task of gaining the necessary capital approval to start N/C burning to be a long, drawn out affair. There has been a tremendous amount of mystery surrounding how the. black box can actually do the things that a human being can do only with years of experience and a sense of judgment. How can a black box exercise judgment? .

But that aura of mystery only contributed to the more tangible problems we faced during the long, arduous task of getting approval for N/C.

At one point about five years ago when the decision was almost made to go ahead, no capital money was available. The subject simply went into a state of limbo a-rid then faded away as time passed.

About three years ago N/C was revived, but most of the discussion centered on whether BIW should use AUTOKON or SPADES . Possibly because there had not already been a firm

decision to make the change to N/C burning before attempting to select which computer system should be used for driving the burning machine, that argument went unresolved, thus causing the subject of N/C to again become suspended. The next and final attempt began over a year ago when the present Industrial Engineering department was organized. One of the first major projects assigned the new department was to again evaluate the feasibility of going to N/C burning.

Many yards that have N/C today have obtained approval based on the many intangible benefits that are inherent to N/C systems. A broad bracket of potential dollar savings can be placed around these benefits, but measurable savings is very different if not impossible to determine. Simply citing the 5 - 15% saving in steel labor that AUTOKON claims is the result yards have experienced, or the 25 - 33% SPADES claims to have saved the yards using their system simply carries no more weight with our management than being a point of reference for dollar savings. It is in no way a statement of a fact that can both be proven to have occurred and can be expected with confidence to occur at BIW.

The information put out by the suppliers includes words such as <u>it is assured that</u> or <u>our own experience plus information from shipyards indicates</u> that X% of manhours per ton can be saved with this system. They go on to explain that a certain percentage will be saved in scrap,and another percentage reduction in lofting manhours can occur and some other percentage in welding. We are then to add the various percentages, multiply times the steel weight of a ship, multiply that times the labor and

overhead rates and finally the answer is that so many million dollars per ship will be saved. That analysis may have worked. for some of the shipyards that have acquired N/C lofting and burning, but it would not work at BIW. Approval of capital expenditures here starts with the question, “What’s the effect on the bottom line?” From there we go to, “What’s the percentage return on investment and how many years is the payback period?” Next, “Prove the source of each and every number used to arrive at those answers.”

This investment in a complete N/C burning system with computer-aid design and lofting represents one-half of the dollars we are presently spending annually on capital equipment. A project of &at magnitude receives very close attention to detail during the approval cycle.

It does not take very long to come to the conclusion that you cannot back up those answers found in the publications presently available with hard facts. We found that detailed backup information on which the percentage savings is based was simply not available.

That's the end of that - no approval.

Six folders of data on N/C burning that had been gathered during evaluation in the previous five years was studied to see if certain pertinent facts could be extracted and a justification put together without another full-blown effort. Dollar savings based on objective, specific facts could not be found in the files. Since a formal written presentation had not

been put together, what the files contained, by and large, was isolated facts. A logical progression of what computer-aided lofting is, how it compares to full scale and l/10th scale lofting, and what N/C burning will do to improve production didn't exist either.

What did exist, however, were very strong opinions among most of the people who had been involved in the previous studies about what was right and what was wrong. Many preconceived notions were held strongly about our needs for new equipment, what systems were best and what should be bought.

The problem was finally defined by management as: (1) our old l/10th scale burning machines are about to collapse and should be replaced before it's too late; (2) N/C burning must be a good technique for shipbuilding because so many yards are using it; and (3) since N/C must be the answer, provide the necessary justification so it can be purchased, considering that (a) two previous attempts failed, and (b) there doesn't appear to be enough tangible evidence . readily available to convincingly settle the advisability of the investment.

Early on, MarAd suggested to us that it may be most productive to pursue the job of getting N/C approved if we <u>first</u> decided if N/C per se was an economical investment for BIW, and <u>secondly</u> to make an evaluation to decide which system would be used -- AUTOKON, SPADES, STEERBEAR, or some other,

It took some time for the imPortance of that advice to become clear. The question can be stated simply: "If more than one brand of automobile will get you from one place to another in the style you require, shouldn't you first decide if you even need a new car at all before you start worrying about whether it should be a Ford or a Chevy?" If you spend all your time on the process of selecting the brand, next year's model may be out before your decision is made.

The value of that advice was not, however, considered to be of great importance at the time a plan was established to analyze the needs of our Fab Shop and justification of Numerical Control. It was coincidental that the study was constructed in such a manner that it worked out that the benefits of computer-aided lofting and N/C plate burning were evaluated first and selection of a brand followed as a separate decision later.

The approach taken was to determine:

1) What are our present real needs and needs for the next five years?

2) If new burning equipment is needed, what are the cost and benefit comparisons of N/C with l/10th scale optical burning machines similar to the present equipment?

In retrospect it was beneficial that the assumption was made at the outset that the need for new burning machines was not necessarily a foregone conclusion, let alone the notion that an N/C burning machine was a necessity. In the organization of BIW there is a long distance from the production floor to the bord room of the directors of Congoleum, our parent company. Attaining the approval of corporate directors located in Milwaukee, Wisconsinfor investing over a million dollars in one project for an old shipyard subsidiary in Bath, Maine, hat hasn’t been adding many dollars to the corporate profit line over the past several years requires more than a statement by Bath Iron Works management that “we know that this capital investment is <u>really</u> good and your approval is, therefore, requested. “

It was decided that we would take a new look at N/C by starting fresh. The old files *were* put in a drawer and a short study made to see if common problems seem to be inherent to getting numerically controlled machines approved in the business community in general. Perhaps we weren’t unique. At the *very* least, the methods that we had been using were not successful.

The study was structured by specific tasks. The titles and condensed results of the tasks are as follows:

1) Present Loading

   Actual labor hours were calculated per plate for Ro/Ro and FFG from 1975 returns and factors

developed for the unplanned “add-work” and special sequences that reduce time available for production.

2) Maintenance Downtime as a Percentage of Production Time

#l and #2 Telerex - 9.2% and 9.3%

Flame Planer - 5% .

#l and #2 CM - 2% and 0.7%

3) Machine Layout/Material Flow Chart - made for the present situation

- Aluminum Deck House Fabrication Location for FFG - Hardings or Bath?

Hardings will cut the plate and, therefore, needs a cutting capability that is faster and requires less flow disruption and handling problems than the present process of sawing. Gas cutting is incapable of processing non-ferrous metals.

4) Material Breakdown and Annual Mix Analysis

Quantities of plates have been identified for each burning operation for Ro/Ro, FFG and Industrial to route quantities of materials to each burning operation for loading purposes.

- Five Year Business Plan - Ship and Industrial: the highest capacity strain situation was determined.

5) Machine Capability

Operating tolerances for each machine were measured and judged to be adequate.

6) Annual Machine Load for the Five Year Plan

CM-56's - 3 shifts, 6 days/week
Flame Plane - 2 shifts, 5 1/2 days/week
Telerex's - 3 shifts, 6 days/week

7) Performance Needs for a New Machine

Desirable burning functions and machine features have been defined, along with plate sizes and materials that will be processed to determine equipment requirements.

8) Repair/Rebuild the Present Telerex's

Mechanical rebuild has been performed on both machines, but it is not economical to recondition the hard-wired, tube-type electrics: cost is $100,000 each for electrical refurbish with no measurable savings resulting.

9) Replacement of present Telerex with comparable 1/10th Scale Optical Directed machine: No savings

10) The N/C Plan Task was, in essence, the resulting proposal submitted to management.

11) Evaluate Costs/Benefits

The financial analysis indicates the return on investment is 28.4%, payback period is 4 years; several intangible benefits are discussed elsewhere.

12) Prepare the Proposal for Management Action.

13) Technical specifics for all equipment purchase orders.

CAN AN N/C SYSTEM BE JUSTIFIED AT BIW?

As soon as the study was under way, it became apparent that common problems of gaining approval of N/C equipment did exist - in most industries. Often justification of the large investment required for the first numerical control machine tool that a company acquires has been very difficult in most industries. The problems are due to the many functions that . are affected by the new process. There are two basic approaches that are usually taken to analyzing the savings that can be anticipated:

1) Identify all areas (production, material control, quality, clerical, etc.) that may be affected by N/C and estimate a dollar savings; or
2) Quantify the dollar savings only in the areas that are significantly affected and can have the results measured in an audit. All other areas that are affected to a nebulous degree aue simply treated verbally - no specific dollar savings is claimed.

The second approach has been taken in this evaluation of using N/C at BIW. It was decided that if there is not enough specific, attainable savings without including nebulous possibilities to justify the investment, it would be unwise to acquire the system.

N/C OR NOT?

Is N/C the panacea for all shipyards, or are there certain conditions that must exist before it becomes beneficial?

Does it depend on ship type and size, or shipyard size, *or are* there other alternatives available today which provide meaningful competition to N/C production machines? As may be obvious, there are no easy, clear-cut answers to these questions, as they involve many factors which are not even constant from one shipyard to another. However, from the experience of shipyards using at least some aspect of N/C, it can generally be stated that N/C applications have always improved the process and resulted in economic savings, regardless of the above-mentioned factors.

Guidelines for the use of N/C in other industries can be studied as a decision aid for a shipyard. It is claimed that a company is ready for N/C when:

1. The number of identical job-runs is relatively small: This is certainly true of ship parts. The number of identical parts is relatively small even for a tanker. Manual drawing or template manufacture time is always greater than that required for N/C data processing.
2. The average part has a fair degree of complexity: Computer-aided programming systems can handle complexity better and quicker than manual methods. Significant savings in time and reduction in scrap are obtainable with N/C. Obviously, the more complex the ship, the more the advantage of N/C. However, even for simple parts, the increased accuracy and simple control with N/C improves results.

3. <u>The parts are subject to frequent design change</u>:

   This is, unfortunately, so in shipbuilding. N/C allows changes to be implemented quickly, providing the capability for processing and managing such changes has been built into the organization.

4. <u>Inspection procedures are lengthy, difficult and, therefore, costly</u>:

   With N/C, the inspection can be performed by checking drawings prepared from the N/C tape. The only checks that must be made of the actual cut parts are to ensure machine accuracy.

The above items are easily definable and when considered directly, show N/C to be competitive. However, the main benefits which accrue from the use of N/C far exceed the above considerations and are usually the reasons for a company to implement N/C. The indirect benefits such as better management and control, which are possible with the use of an N/C system, are also of considerable significance.

The approval of the project at BIW rested almost completely on the return shown in the financial analysis. The final results of the financial analysis were based on the marketing projection of ships that would be built and the quantified labor savings in fitting and welding for each hull. The development of the labor savings is the heart of the N/C justification.

PRESENT

JOINT OPENINGS

52%	0 -1/16 INCH
22%	1/16 -1/8 INCH
18%	1/8 - 1/4 INCH
8%	+ 1/4 INCH

LABOR HOURS PER FOOT

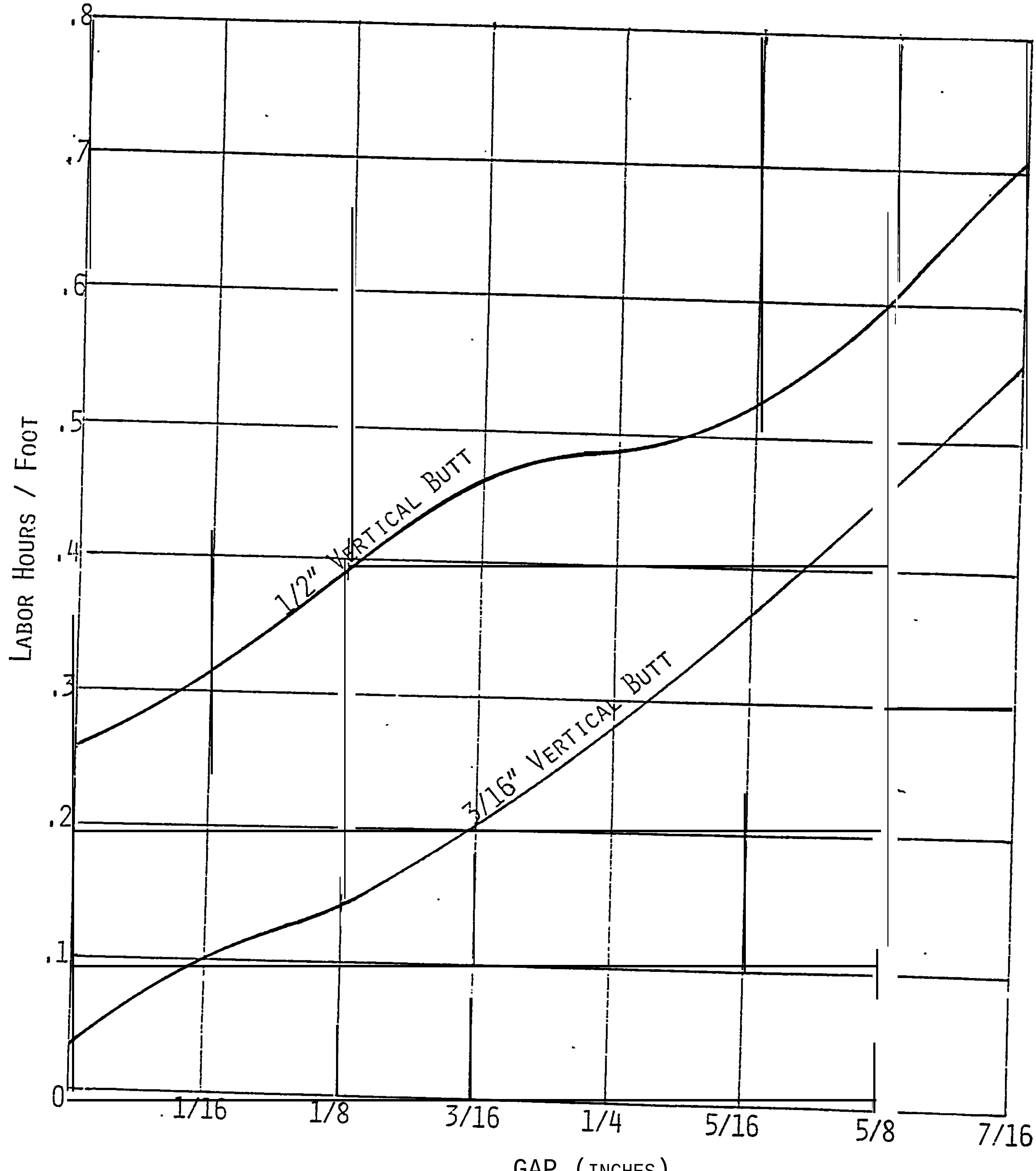
7018 HORIZONTAL FILLET WELD

GAP (ROOT OPENING, INCHES)

WELD SIZE (INCHES)	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
3/16	.019	.039	.090	.119	.137	.197	.301	.405
1/4	.023	.043	.107	.127	.104	.205	.345	.429
5/16	.043	.003	.115	.155	.172	.249	.368	.453
3/8	.060	.010	.142	.163	.216	.273	.395	.482
7/16	.068	.081	.150	.207	.240	.297	.435	.512
1/2	.095	.115	.194	.231	.264	.327	.465	.531

ARC TIME VS OPENING

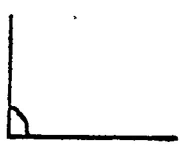
FIRST SIDE - 7o18



COST MULTIPLIER ASSEMBLY BUILDING

HORIZONTAL FILLETS

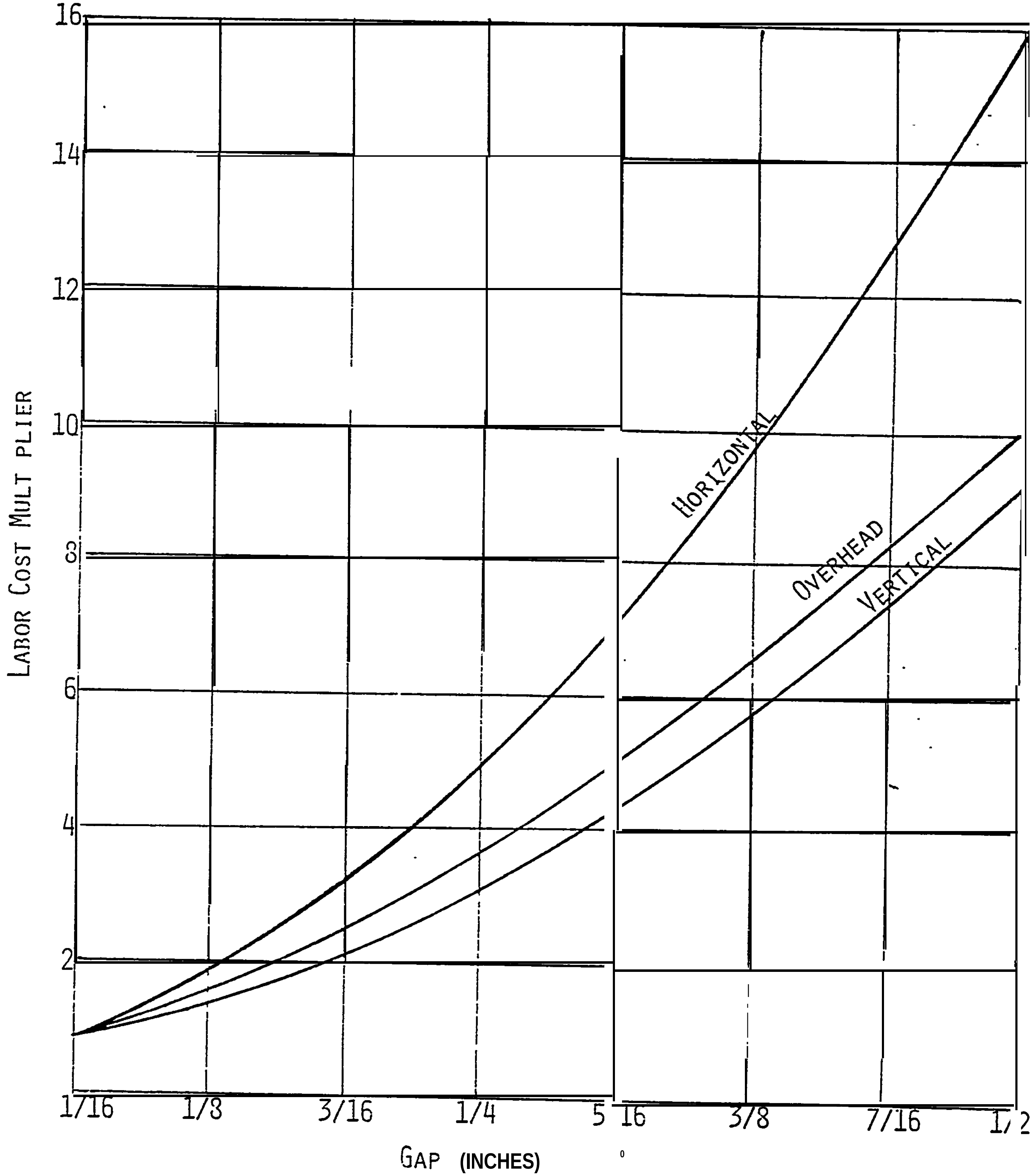
	WELD SIZE					
	3/16	1/4	5/16	3/8	7/16	1/2
BKHD TO FLAT PANEL	2.2	2.0	1.7	1.5	1.4	1.3
BKHD TO CURVED PANEL	2.4	2.2	1.8	1.6	1.5	1.4
STIFF TO FLAT PANEL	1,4	1,4	1,3	1,2	1,2	1,1
STIFF TO CURVED PANEL	2,2	2,0	1,7	1,5	1,4	1,3



	WELD SIZE					
	3/16	1/4	5/16	3/8	7/16	1/2
BKHD TO FLAT PANEL	2,4	2,2	1,8	1,6	1,5	1,4
BKHD TO CURVED PANEL	3,2	2,9	2,3	1,9	1,8	1,6

	WELD SIZE					
	3/16	1/4	5/16	3/8	7/16	1/2
BKHD TO FLAT PANEL	2,4	2,2	1,8	1,6	1,5	1,4
BKHD TO CURVED PANEL	3,2	2,9	2,3	1,9	1,8	1,6
STIFF TO FLAT PANEL	1,4	1,4	1,3	1,2	1,2	1,1
STIFF TO CURVED PANEL	2,2	2,0	1,7	1,5	1,4	1,3

WELDING LABOR VS OPENING, FILLET WELDS



COST MULTIPLIERS

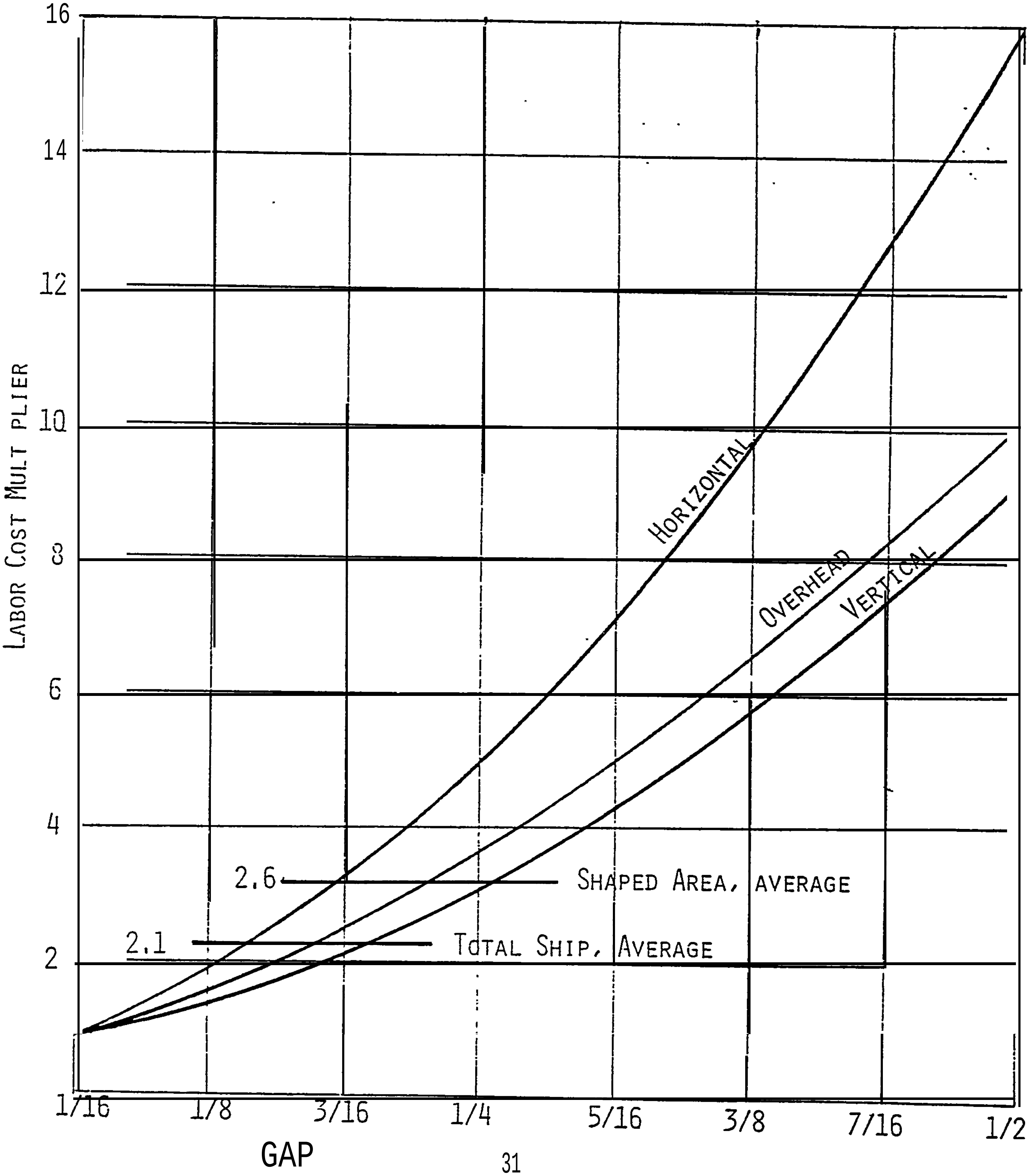
FOR ACTUAL

JOINT OPENINGS

		COST MULTIPLIER
52%	0 -1/16 INCH	1,0
22%	1/16 - 1/8 INCH	2,0
18%	1/8 -1/4	4,0
8%	+ 1/4	7,0
100%	WEIGHTED AVERAGE	2,1

22% OF THE WELDING IS 1/16" - 1/8" OPEN WHICH REQUIRES TWICE AS MUCH LABOR AND MATERIAL AS DO TIGHT JOINTS (0 - 1/16"),

WELDING LABOR vs OPENING, FILLET WELDS



STEPS FOR SAVINGS

1) DETERMINE THE PRESENT AVERAGE GAP FOR ALL WELDING AND FOR AREAS THAT WILL BE CUT WITH N/c,

2) DETERMINE THE WELDING AND FITTING LABOR FOR-THE WHOLE SHIP,

3) ISOLATE THE AREAS IN WHICH N/C BURNING CAN IMPROVE THE FIT AS A PORTION OF THE WHOLE SHIP,

4) BASED ON THE PERTINENT VARIABLES AFFECTING WELDING LABOR, QUANTIFY THE PRESENT LABOR FOR FITTING AND WELDING FOR THE WHOLE SHIP AND FOR THE AREA N/C WILL AFFECT,

5) CORRELATE THE ABOVE LABOR HOURS WITH THE APPROPRIATE TONS OF STEEL (FOOTAGE OF WELDING IS MUCH PREFERRED. IF POSSIBLE) TO ARRIVE AT PRESENT MH/T (MANHOURS PER TON) .

6) PRESENT. MH/T IN AREA AFFECTED
   X TONS AFFECTED
   X PRESENT COST MULTIPLIER

   PRESENT LABOR

7) PRESENT MH/T IN AREA AFFECTED
   X TONS AFFECTED
   X PROPOSED COST MULTIPLIER

   PROPOSED LABOR

3) PRESENT LABOR
   \- PROPOSED .LABOR

   NET LABOR SAVINGS PER HULL WITH N/C

BENEFITS OF CAD
ADDED TO R.O. I.

- MORE INDEPENDENCE FROM DESIGN AGENT

  BETTER PLAN INFORMATION AND ON-TIME COMPLETIONS

- BETTER CHANGE CCNTROL

  THE COMPUTER IS FASTER, CHEAPER, MORE ACCURATE

ŽMANHOUR SAVING IN THE LOFT

- BURNING CAPACITY INCREASE AND LABOR SAVINGS

  N/C GAS BURNING IS FASTER AND PLASMA IS MUCH FASTER THAN GAS

ŽNON-FERROUS AND STAINLESS CUTTING CAPABILITY

  PLASMA

ŽSHIP DELIVERY SCHEDULE SAVINGS

DECISIONS

- BUY AN N/C BURNING MACHINE WITH PLASMA

- USE AUTOKON

- LINDE IS THE PRIME SUPPLIER

ŽANDERSON ENGINEERS WATER TABLE CCNVEYOR

- START UP FOURTH QUARTER 1977

A LOW COST PARTS DEFINITION SYSTEM

Arthur F. Kaun
Newport News Shipbuilding and Dry Dock Company
Newport News, Virginia

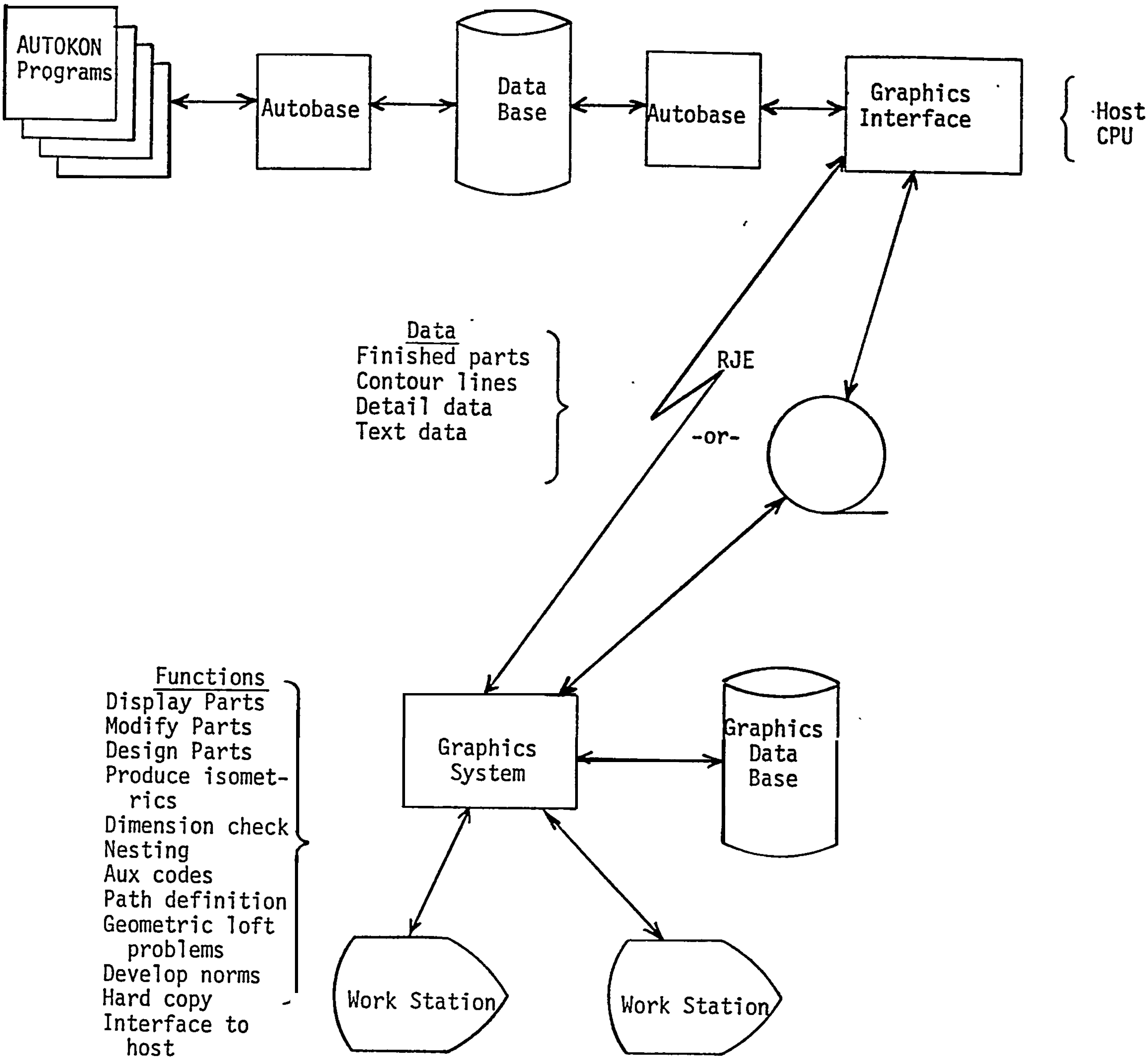
Mr. Kaun is currently developing an interactive graphics approach to parts definition for NNSDD in accordance with the MarAd funded project. He is also responsible for the general support of AUTOKON and related computer systems.

LOW COST PARTS DEFINITION

Benefits

1. Utiilize Graphical Skills
2. Reduce Computer Costs
3. Increase Thruput
4. Reduce Plotting
5. Introduce New Capabilities

Interactive Graphics Parts Definition



GRAPHICS SYSTEM

Data Handling

1. Interface to host
2. Retrieve and disp'ay
   A. Parts
   B. Contours
   C. Data
      Specifications
3. Store data
4. Retrieve norms

Design Graphics

1. Geometric package
   A. New parts
   B. Modify parts
   C. Loft problems
2. Contour usage
3. Norm usage
4. Layering
5. AUX codes
6. Path definition

Util ties

1. Isometrics
2. Nesting
3. Norm development
4. Dimension checking
5. Hard copy
6. Remote Job Entry
7. Post processors
8. Digitizing

ACTION TO DATE

1. Interviewed Five Vendors
2. Part Development Exercise
3. Data Specifications
4. User Review Group
5 Budgetary Quotes
6. Tektronix PLOT/PEDIT
7. Develop Benchmark

PLANNED ACTION

July 1977

- Perform Benchmarks
- Possible Demo for User Review Group
- Analyze Benchmark Results

August 1977

- Develop System Design Specs
- Final User Review Group Meeting
- Final Report

COMPUTER-AIDED ENGINEERING AND DRAFTING IN SHIPBUILDING

Robert A. Cowan
Computervision Corporation
Bedford, Massachusetts

As Manager, Federal Systems, Dr. Cowan is responsible for sales and technical coordination of all major federal projects in Maryland, Virginia and the District,of Columbia. . Before joining Computervision, he was President of Applied Programming Technology (a Gerber Scientific subsidiary) and also performed independent software contracting and consulting.

Dr. Cowan has a B.S. degree from Brown University and M.S. and Ph.D. degrees from Case Institute of Technology.

PROBLEMS COMPANIES FACE TODAY

- HIGH COST OF CREATING DESIGN DOCUMENTATION
- RISING COST OF MANPOWER
- TIME WASTED ON TEDIOUS REPETITIVE TASKS
- LACK OF STANDARDIZATION
- PEAK WORK LOAD SITUATIONS
- REJECTED FINISHED PARTS
- TRIAL AND ERROR APPROACH TO PARTS PROGRAMMING
- LONG PRODUCT LEAD TIMES

RESULT OF THESE PROBLEMS

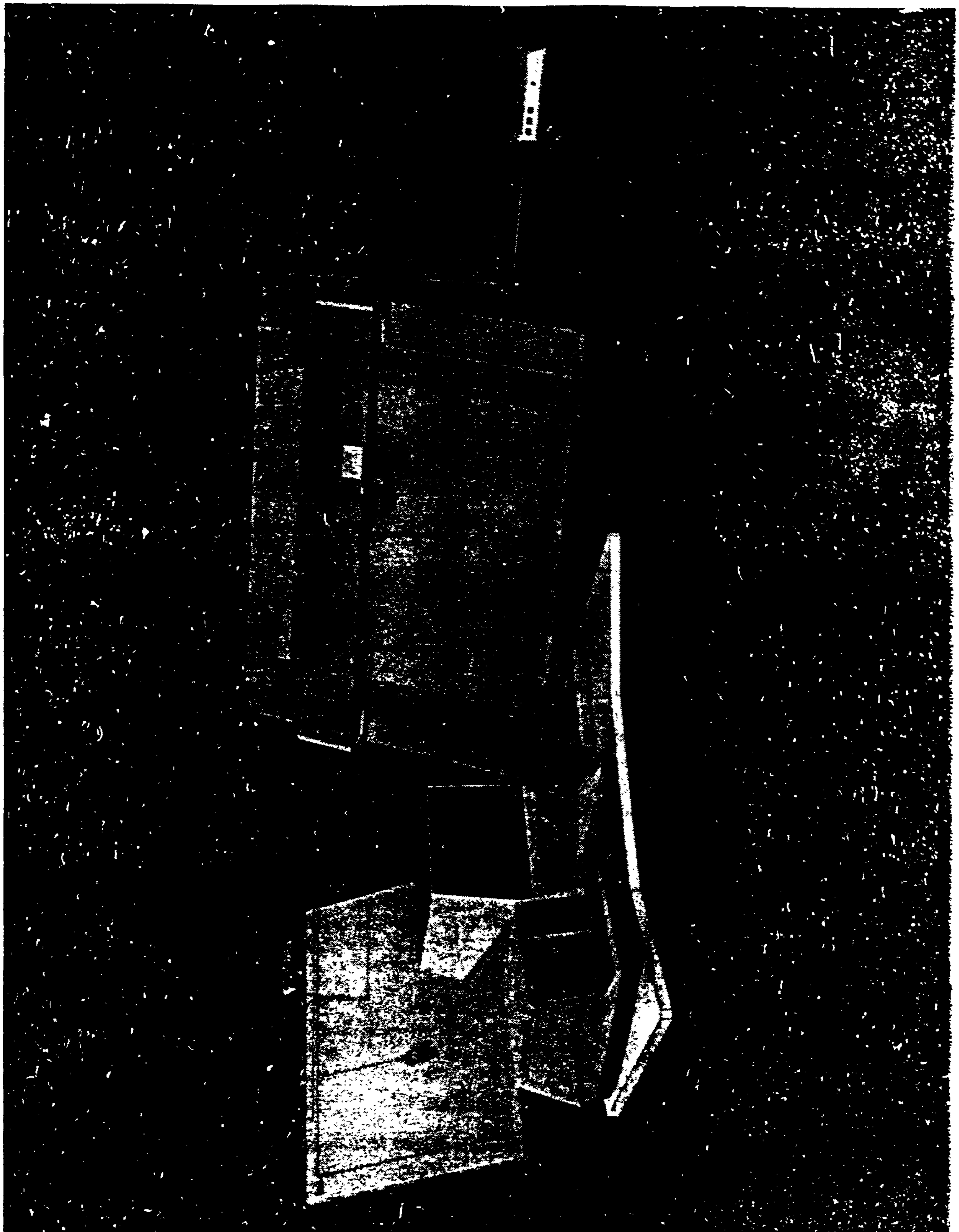
– WASTED COMPANY RESOURCES

RESULTING IN

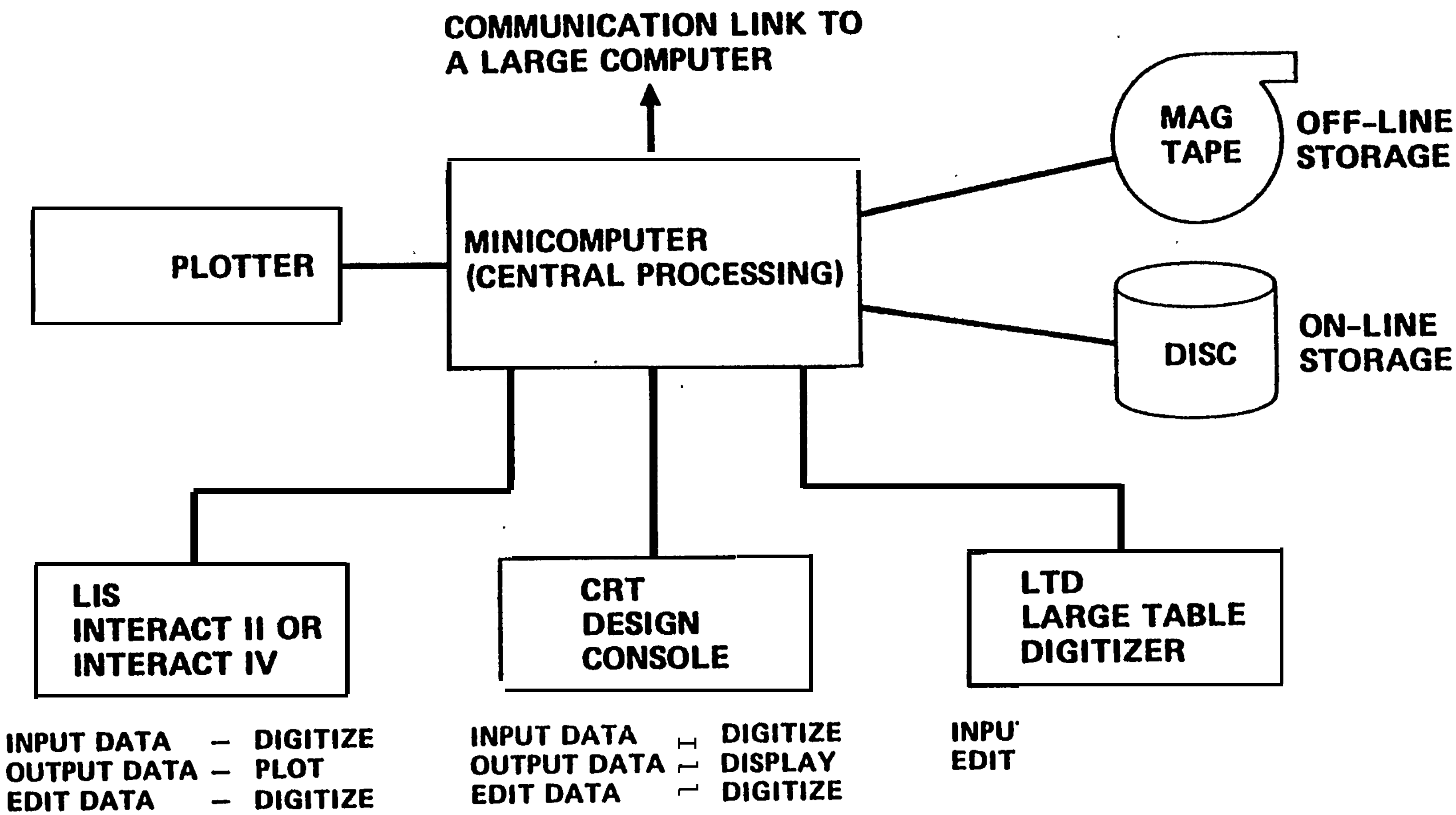
– INCREASED PRODUCT COST
- REDUCED PRODUCTION
- REDUCED COMPETITIVE POSITION

BOTTOM LINE .

– LOST $$'s



FUNCTIONAL SYSTEM DIAGRAM



SYSTEM HARDWARE AND SOFTWARE

HARDWARE

PLOTTER/DIGITIZERS

CRT's

DIGITIZERS

PHOTOPLOTTERS

AUTOMATIC SCANNER

PLOTTERS

FULL RANGE OF COMPUTER PERIPHERALS

SOFTWARE

100% FORTRAN BASED

SIMULTANEOUS, COMPATIBLE 3D AND 2D DATA BASES

SIMULTANEOUS, MULTI-APPLICATION

PEP

DATA BASE MANAGEMENT

MULTI-TERMINAL OPERATING SYSTEM AND FILE MANAGER

OPTIMIZED MAN-MACHINE INTERFACE

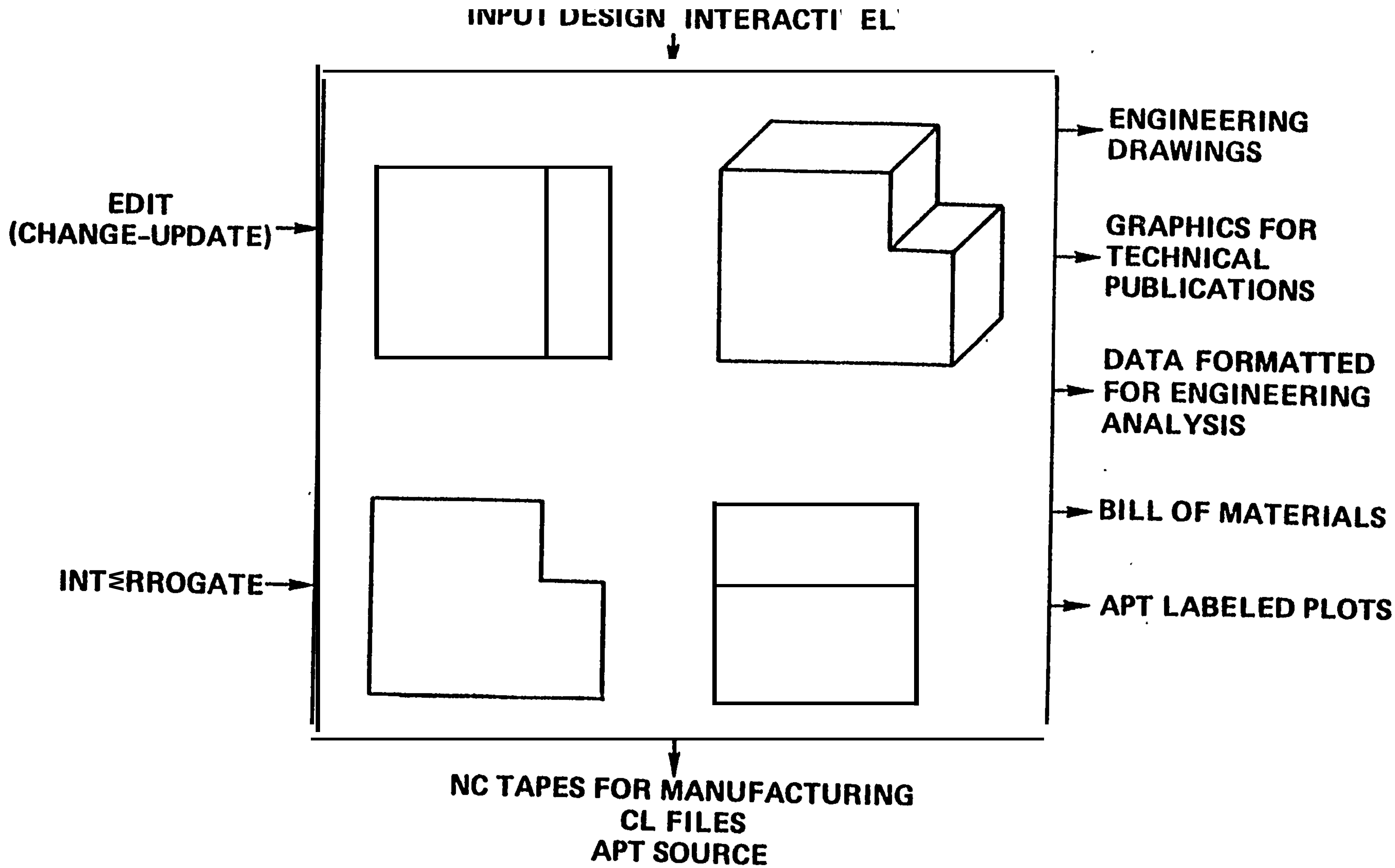
SELF-TUTORING

FORTRAN COMPILER

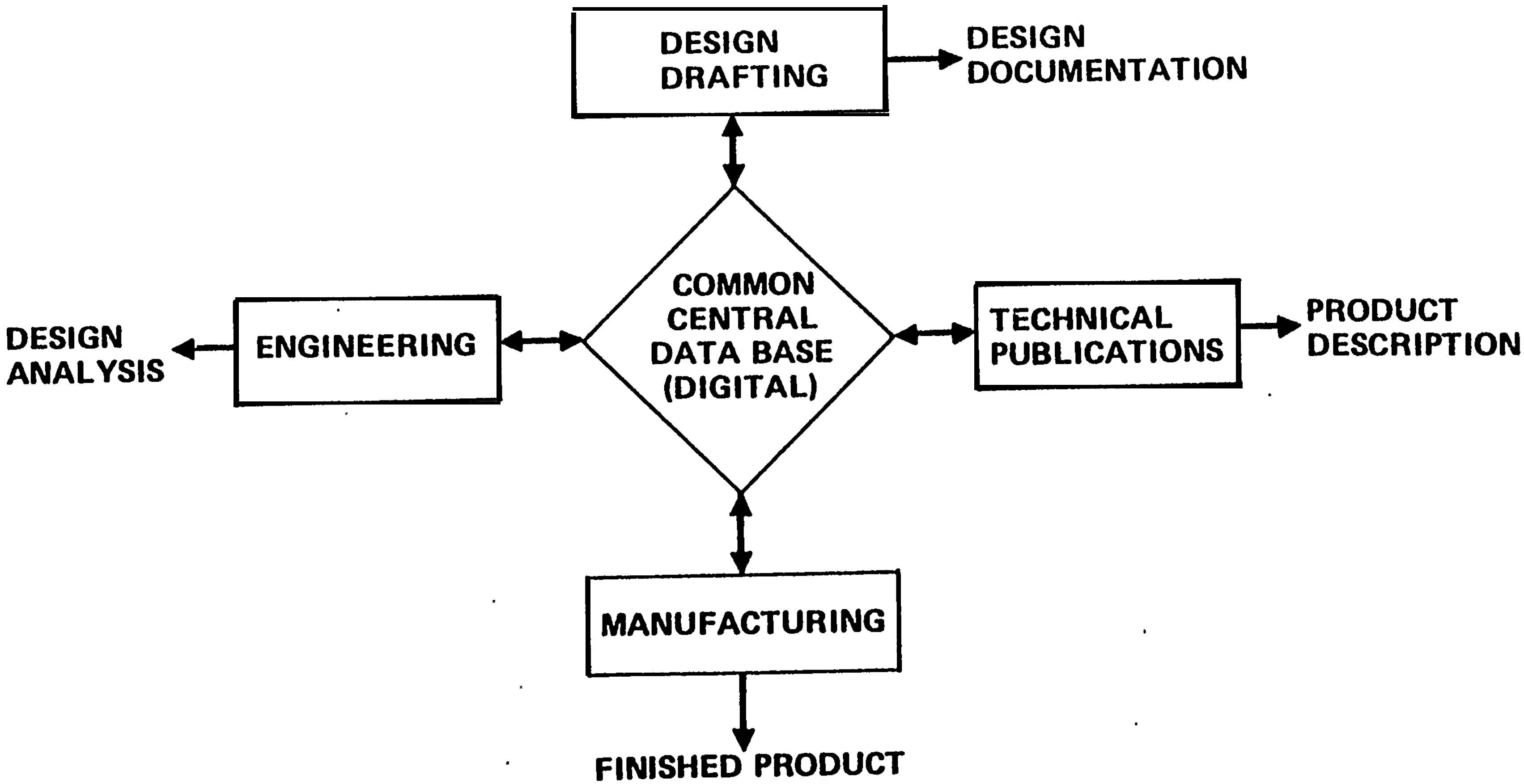
NC POST PROCESSORS

ACCOUNTING FEATURES

3D MD/NC SYSTEM OVERVIEW



CENTRAL DATA BASE CONCEPT

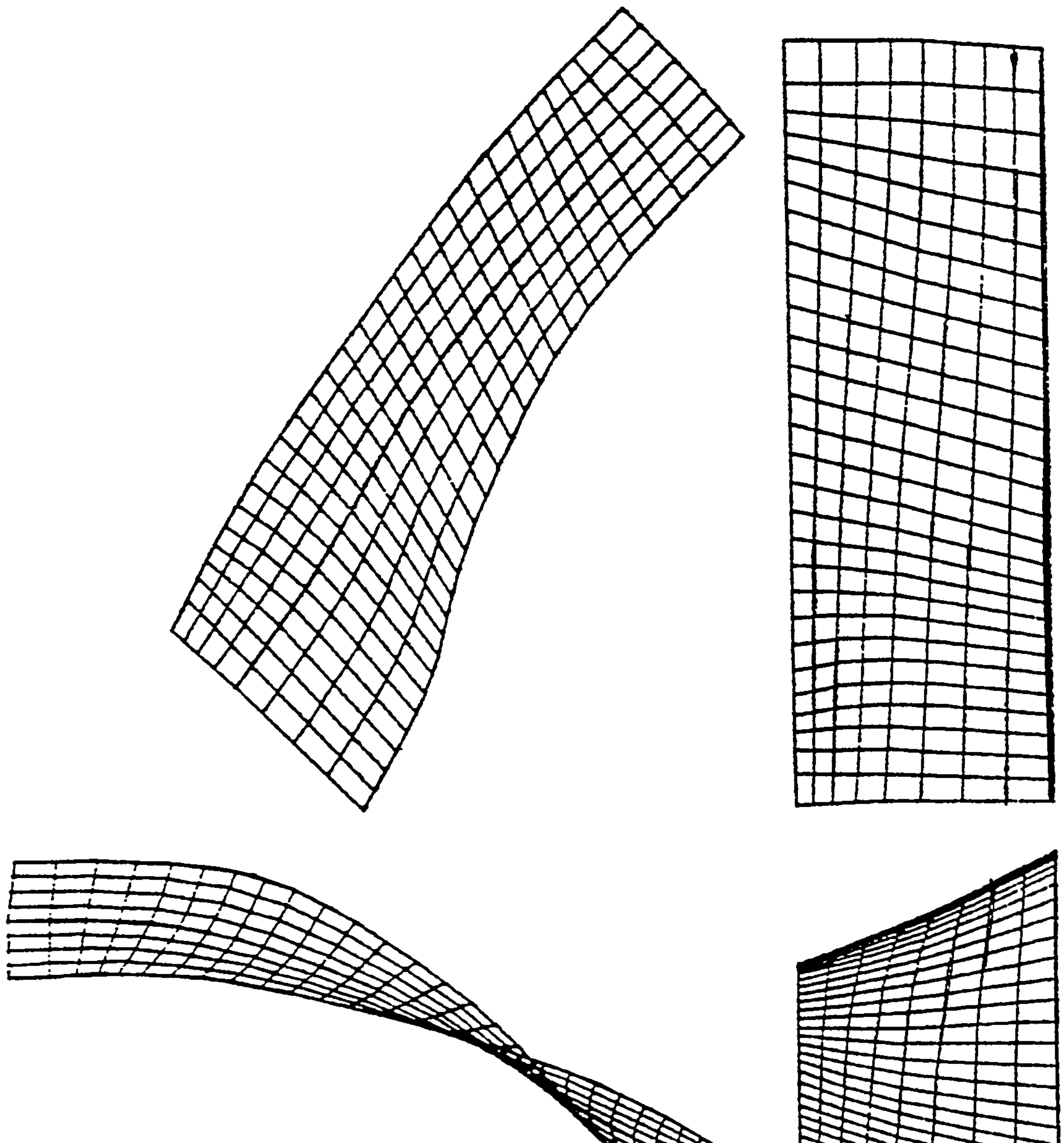


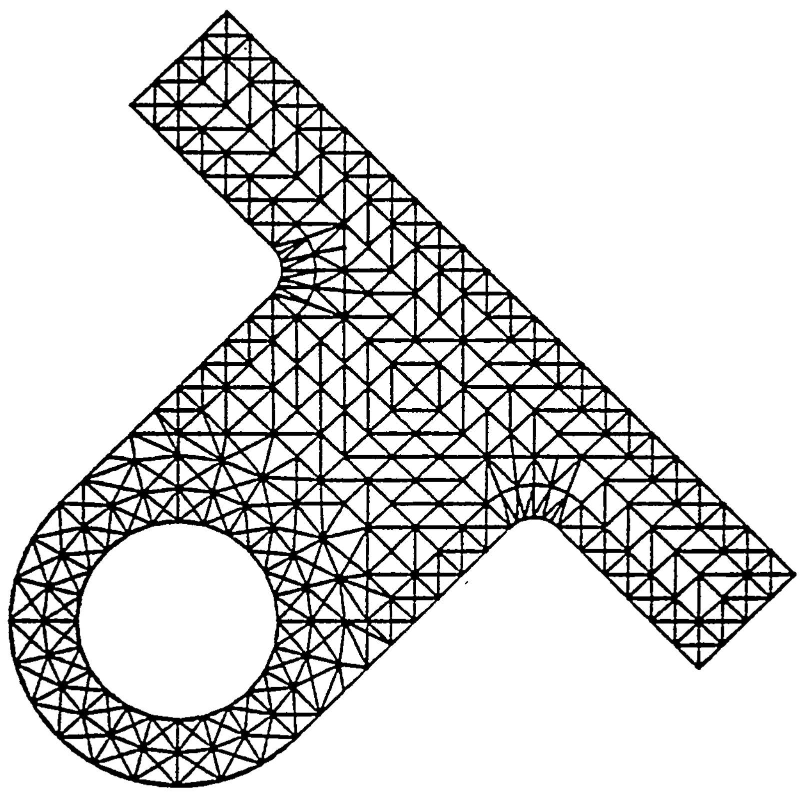
DESIGN ON INTERACTIVE GRAPHIC SYSTEMS

- AREA, PERIMETER, LENGTH, VOLUME, DENSITY, WEIGHT
- 3D DISTANCE
- MINIMUM DISTANCE
- INTERSECTING LINES
- INTERSECTING LINES AND PLANES
- INTERFERENCE AND CLEARANCE
- TOLERANCE STACKING
- STRESS, STRAIN, THERMAL EXPANSION
- FIT PARTS TOGETHER
- CROSS-SECTION
- INTERSECTION OF SURFACES

+

ALL THE GEOMETRIC CONSTRUCTIONS





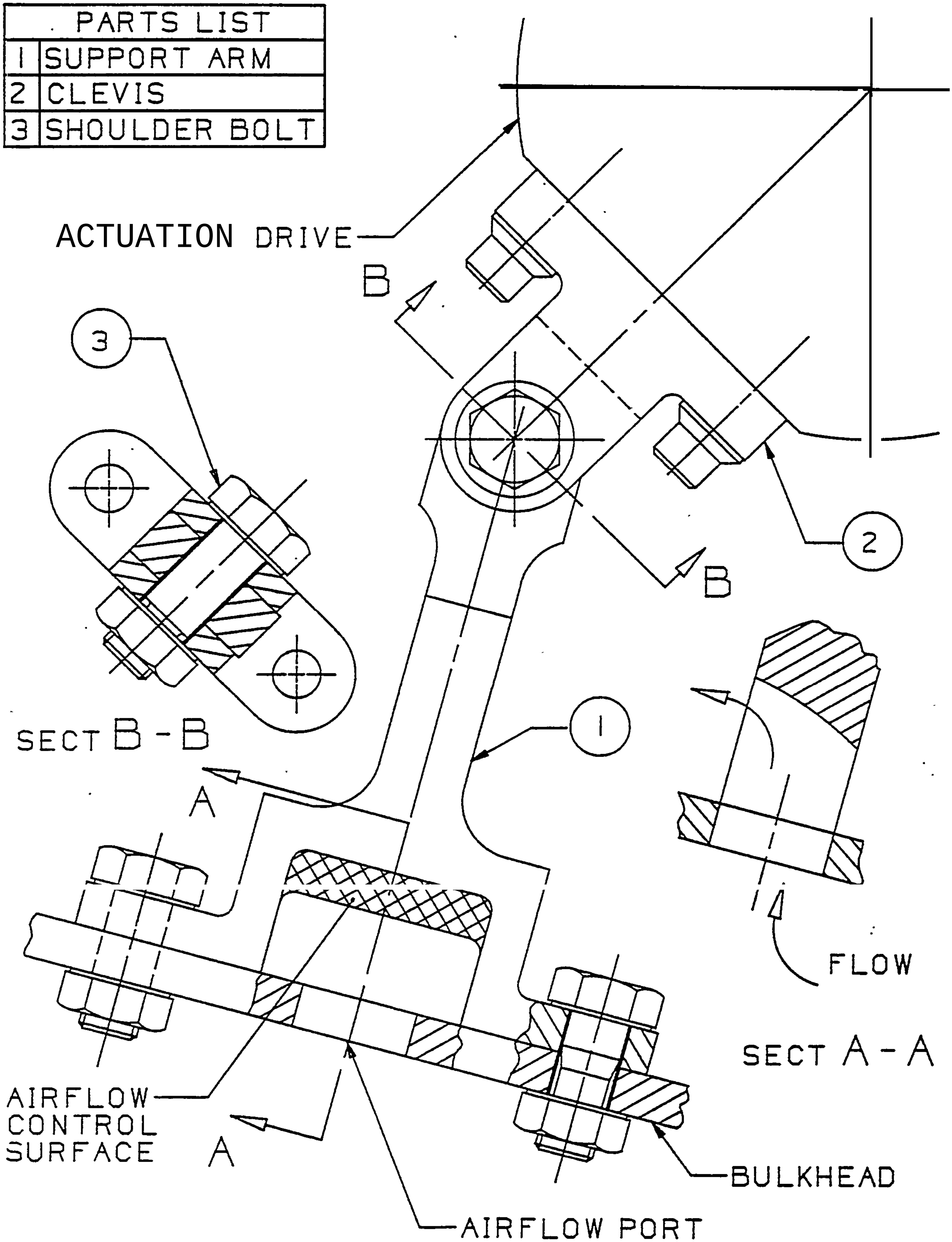
DRAFTING ON INTERACTIVE GRAPHIC SYSTEMS

- ISOMETRIC VIEWS
- CROSS-SECTIONS
- DIMENSIONING (ENGLISH & METRIC)
- CROSS-HATCHING
- FILLETS
- FEATURE CONTROL SYMBOLS
- SCALE, COPY, ROTATE, MIRROR, DELETE ETC.

ONCE DESIGN IS COMPLETED THE DRAFTSMAN CAN EASILY CREAT FINISHED DRAWINGS OF PARTS AND ASSEMBLIES

- HIGHER QUALITY DRAWINGS
- IN A SHORTER PERIOD OF TIME
- AT A REDUCED COST

PARTS LIST	
1	SUPPORT ARM
2	CLEVIS
3	SHOULDER BOLT



BASIC GEOMETRY

POINT

LINE

STRING

CIRCLE

ARC

GROUPS

FILLET

SPLINE
(CUBIC)

CONICS
(ELLIPSE)
(HYPERBOLA)
(PARABOLA)

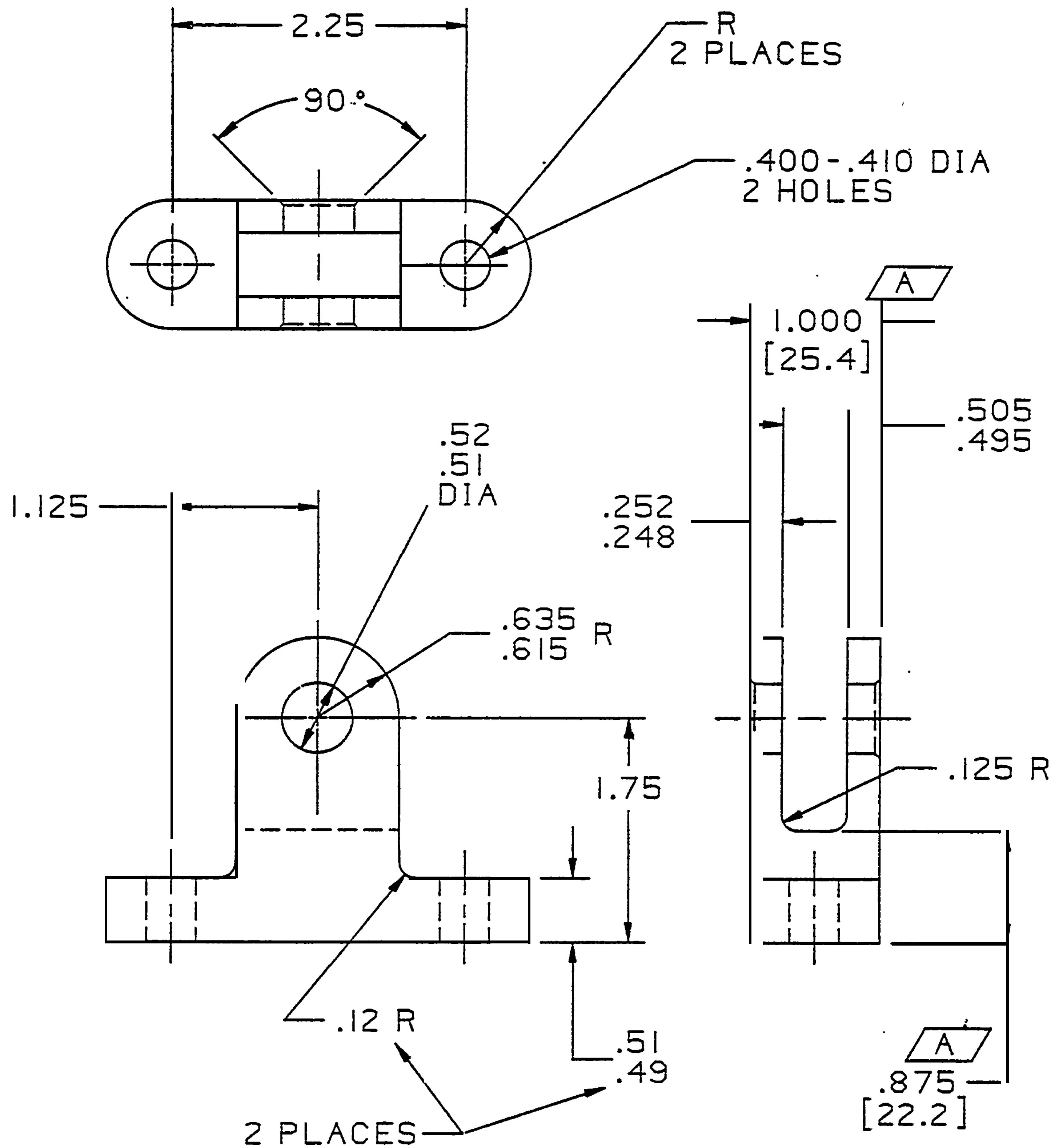
ARRAYS
(RECTANGULAR)
(CIRCULAR)

EXTENDED GEOMETRY

- TABULATED CYLINDERS
- RULED SURFACES
- SURFACES OF REVOLUTION
- B-SURFACES
- MESH SURFACES
- SURFACE NTERSECTIONS

AUTOMATIC DIMENSIONING

- ENGLISH/METRIC
- HORIZONTAL
- VERTICAL
- RADIAL
- DIAMETER
- ANGULAR
- PARALLEL POINTS (DIMENSIONS AT AN ANGLE)
- AUTOMATIC TOLERANCING
- ANS Y14.5



GENERAL NOTES

1 — DIM SPECIFIED MUST BE MAINTAINED.
2 — /A/ DIM SHOWN IN ENGLISH AND METRIC FORM.

PEP PROGRAM (WEDGE)

```
PEP' JRIIS. WEDGE
  SOURCE  VERSION  #  137  7-11-75
  OBJECT  VERSION  **NONE**
```

```
PARTNO/WEDGE
$PARAMETERS
A=2 .5            $LENGTH
B=A*COS (75)                  $THICK
C=2 .5            $CONSTANT
D=.2              $DENSITY
$PART DEFINED
```

FORTRAN PARAMETERS CONSTANTS

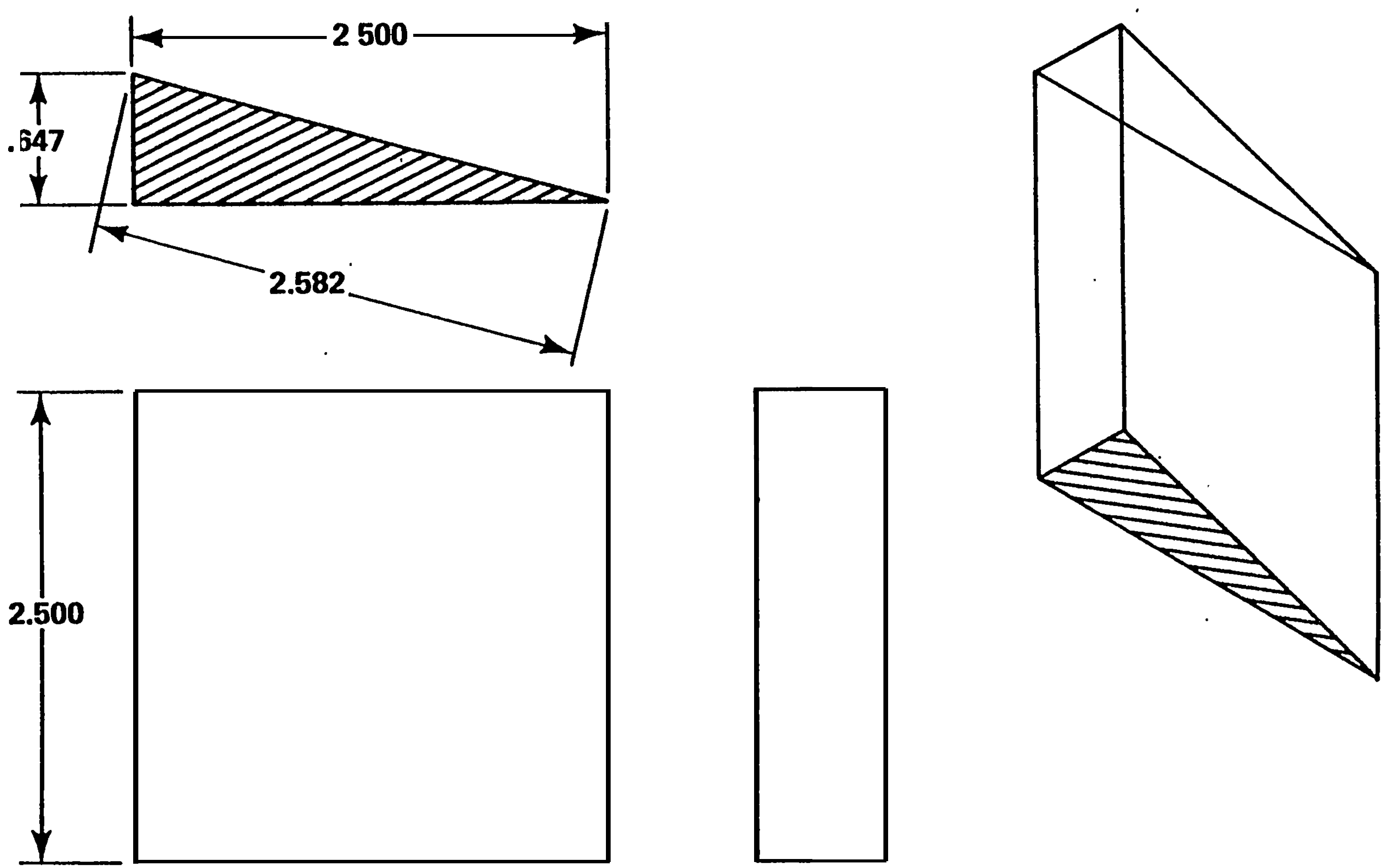
```
L1=LINE/0,0,A,0
L2=LINE/A, O, O, B
L3=uNE/o,  B,o,  o
L4=LINE/o,  o,o,  o,o,  c
L5=LINE/o,  o,c,  A,o,  c
L6=LI NE/A, O,C, A, 0,0
L7=LINE/A, O,C, O, B, C
L8=LINE/0, B,C, O, B, O
L9=LINE/0, B, C, 0,0, C
```

APT TYPE STATEMENTS GRAPHICS

```
AREA=A*B/2
VOLU-AREA*D
WGT=VOLU*D
PRINT/AREA,  VOLU,  WGT
FILE
FINI
```

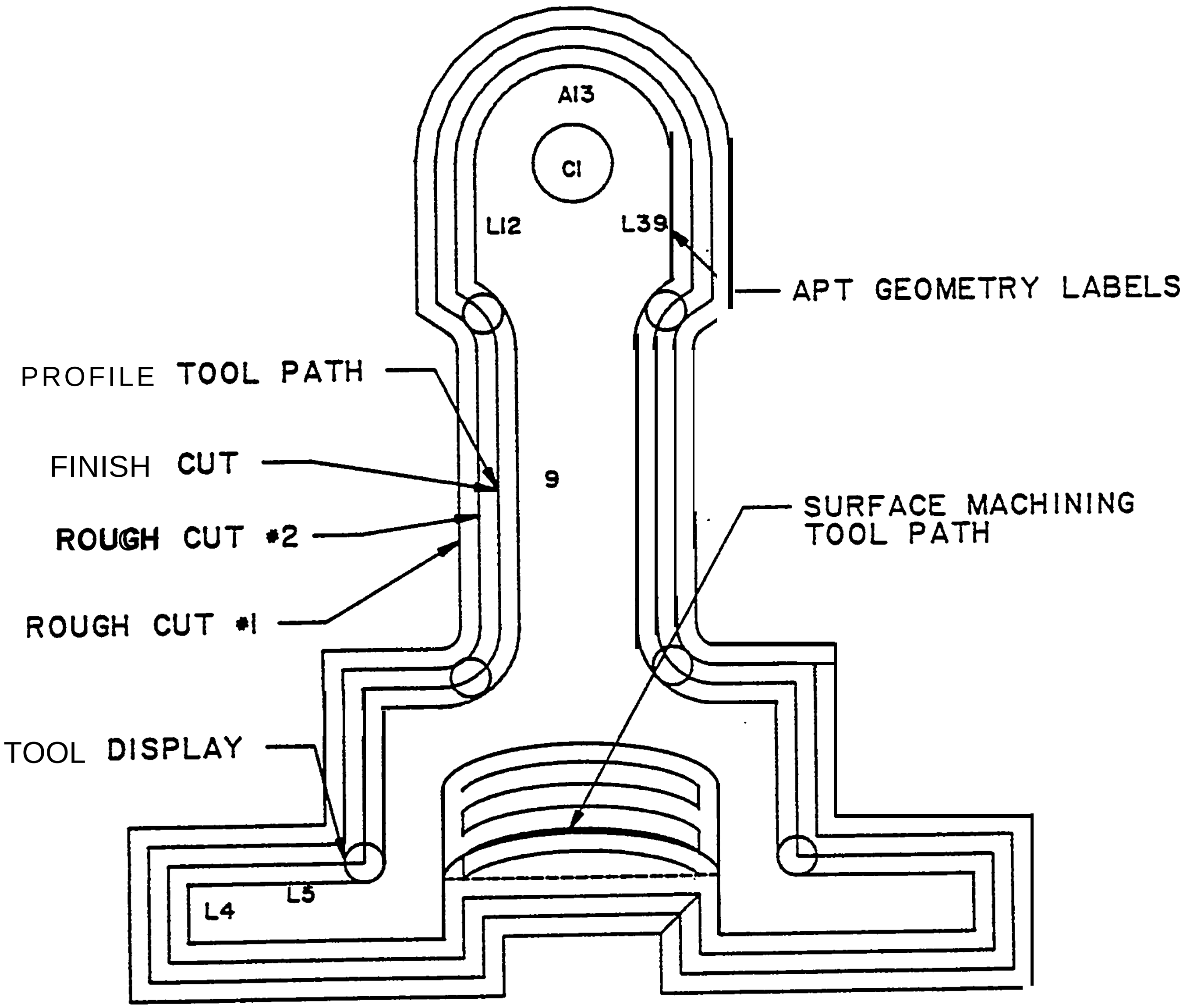
FORTRAN CALCULATIONS

THE FOUR VIEWS OF A WEDGE, RESULTED FROM EXECUTING THIS PROGRAM



NUMERICAL CONTROL

- GRAPHIC TOOL PATH DERIVATION
- UP TO 5-AXIS CAPABILITY
- POCKETING
- PROFILING
- POINT TO POINT
- ABSOLUTE AND SURFACE MACHINING
- APT SOURCE, APT GEOMETRIC SOURCE, APT LABEL PLOT (AUTOMATIC TAGGING), CL FILES, NC TAPES
- POST PROCESSORS
- MAGNETIC OR PAPER TAPE OUTPUT



A13
C1
L12
L39
APT GEOMETRY LABELS
PROFILE TOOL PATH
FINISH CUT
9
SURFACE MACHINING TOOL PATH
ROUGH CUT #2
ROUGH CUT #1
TOOL DISPLAY
L5
L4

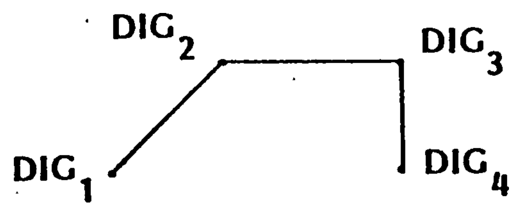
HOW DO PEOPLE INTERFACE WITH THE SYSTEM?

- NO COMPUTER KNOWLEDGE REQUIRED
- EASY TO LEARN ENGLISH LANGUAGE COMMANDS
- SELF-TUTORING

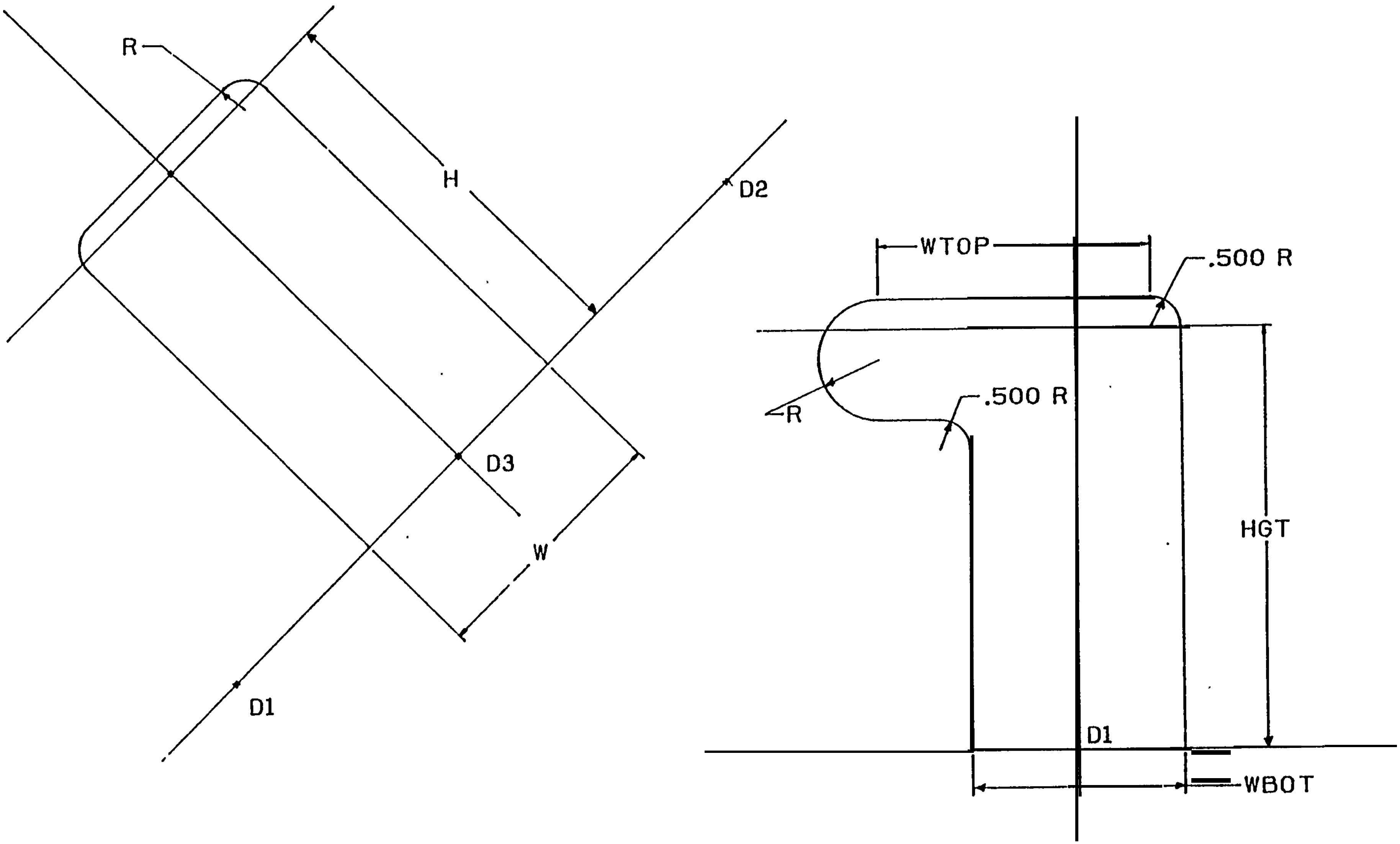
COMMAND LANGUAGE

VERB NOUN: DIGITIZE

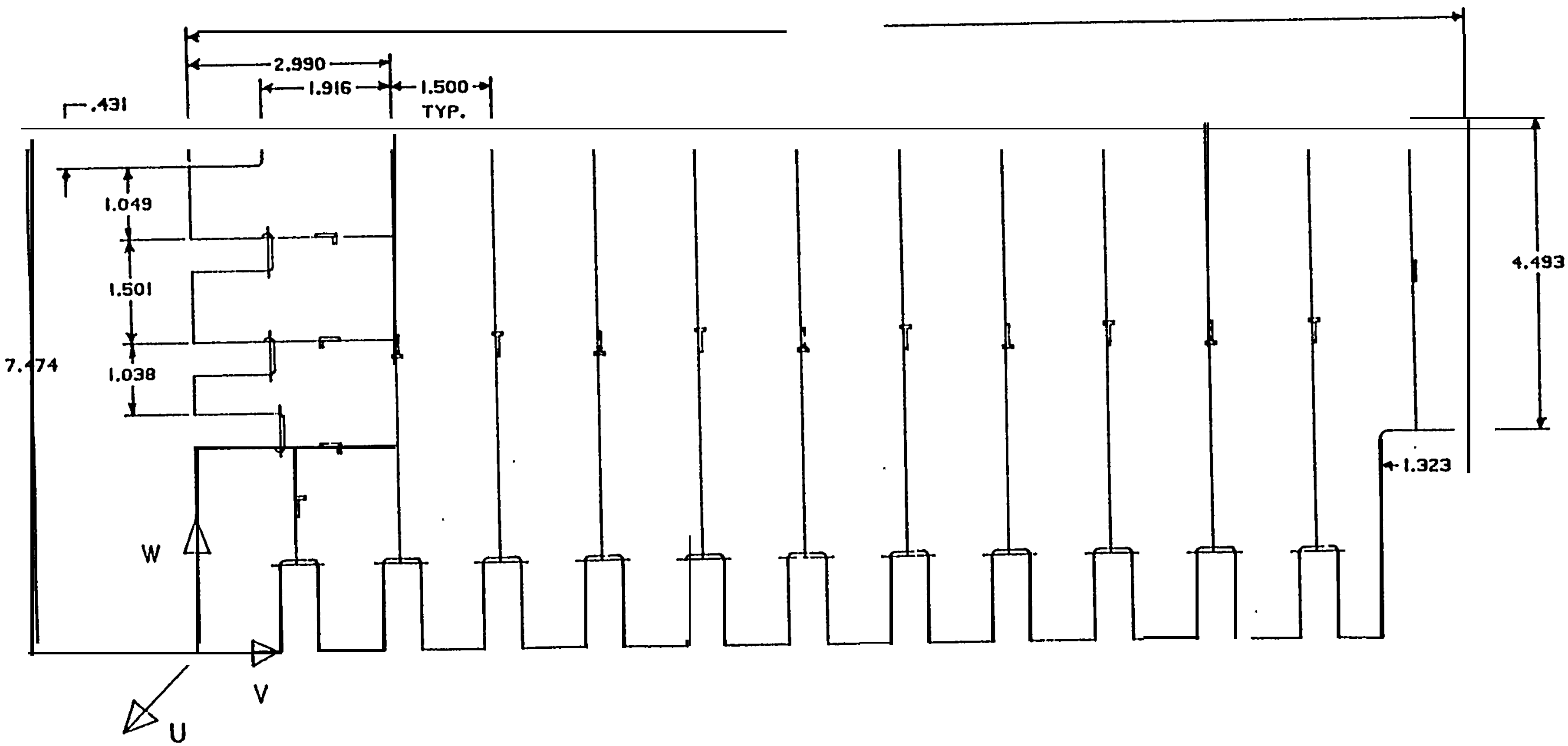
EXAMPLE: INSERT A SERIES OF CONNECTED LINES



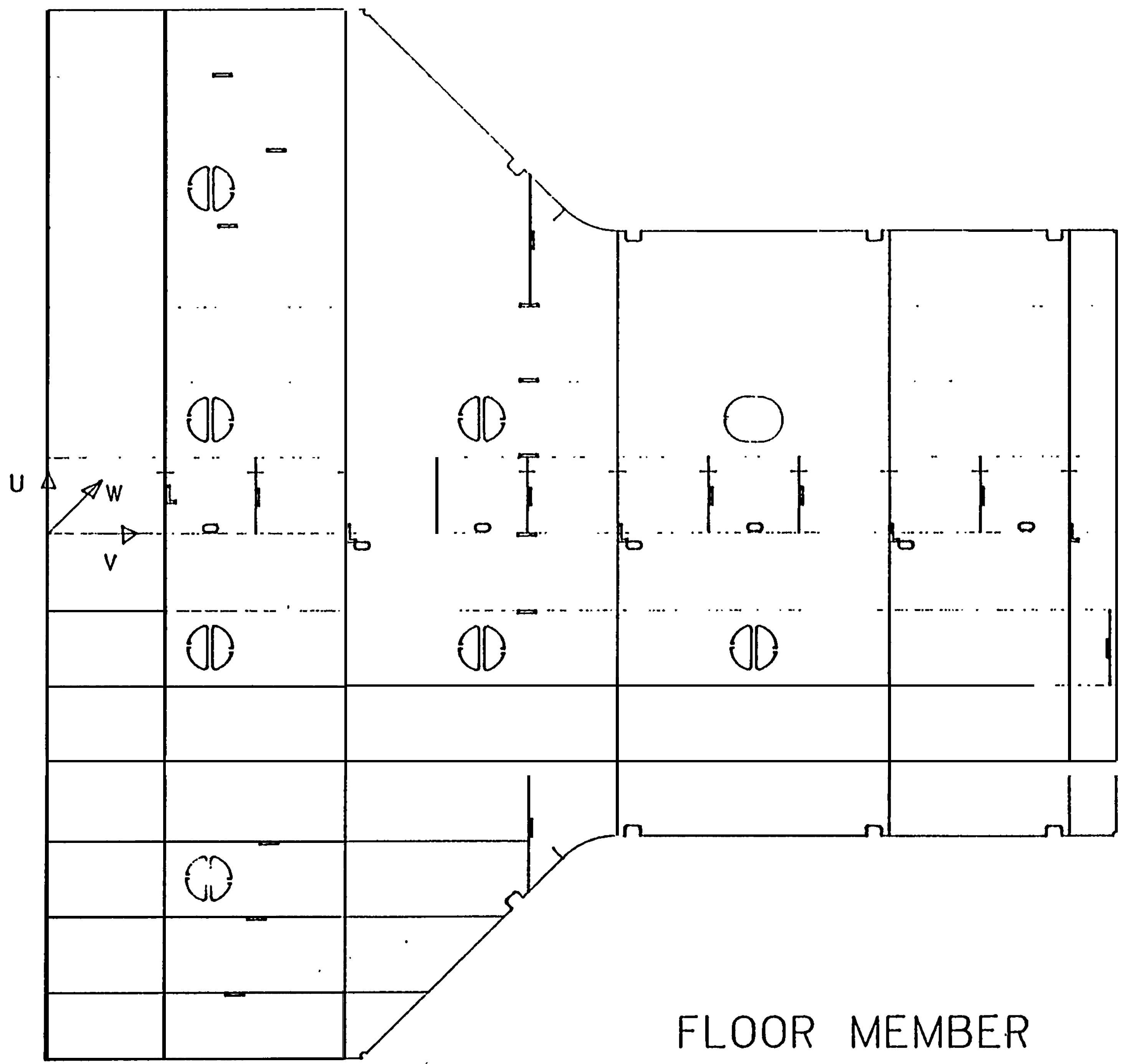
INS LIN: DIG, DIG_2 DIG_3 DIG_4



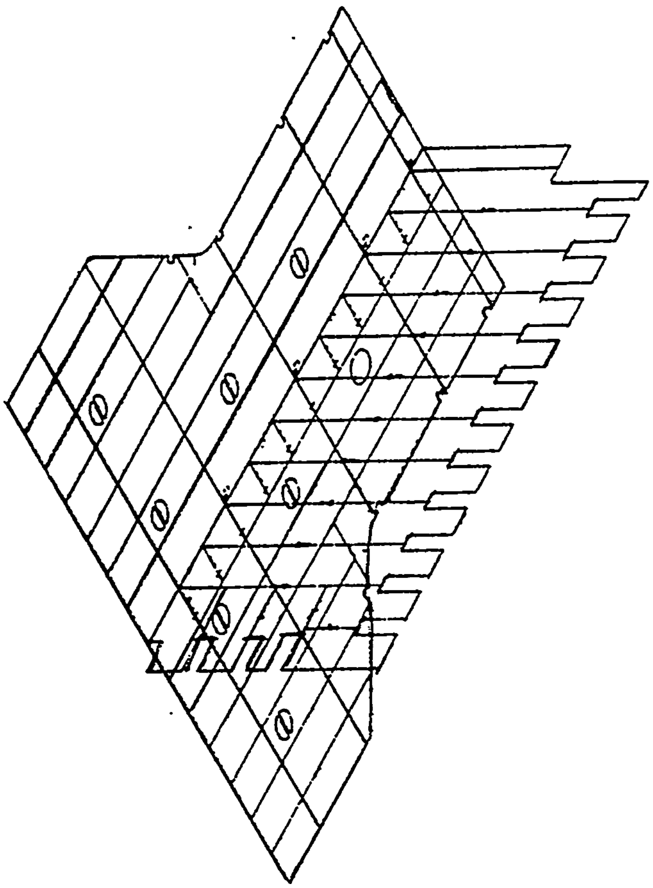
TYPICAL NORMS ENTERED USING PEP AND A
COMBINATION OF PARAMETERS AND DIGITIZED DATA

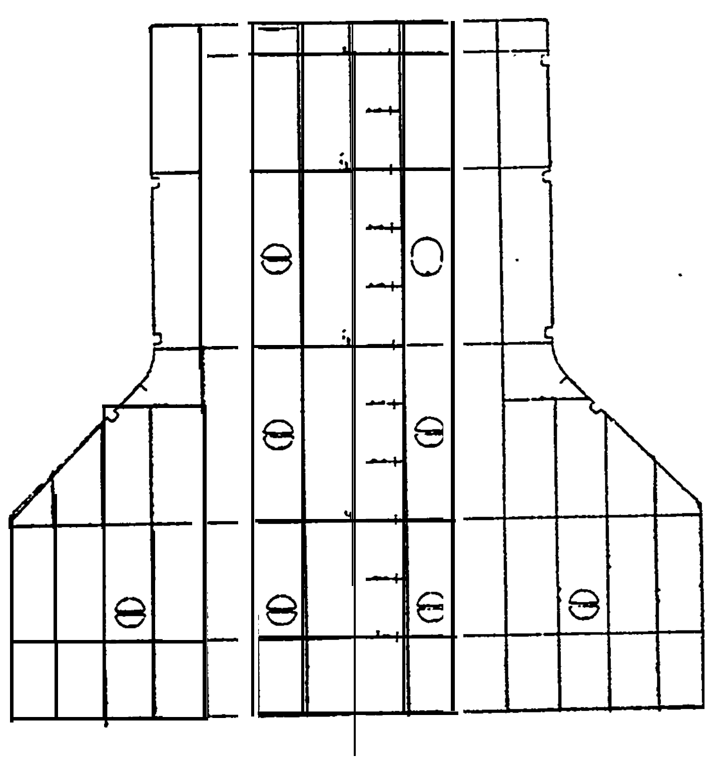


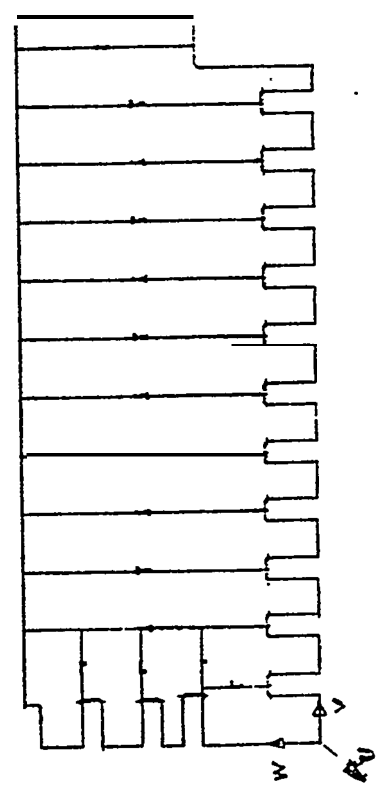
VERTICAL MEMBER

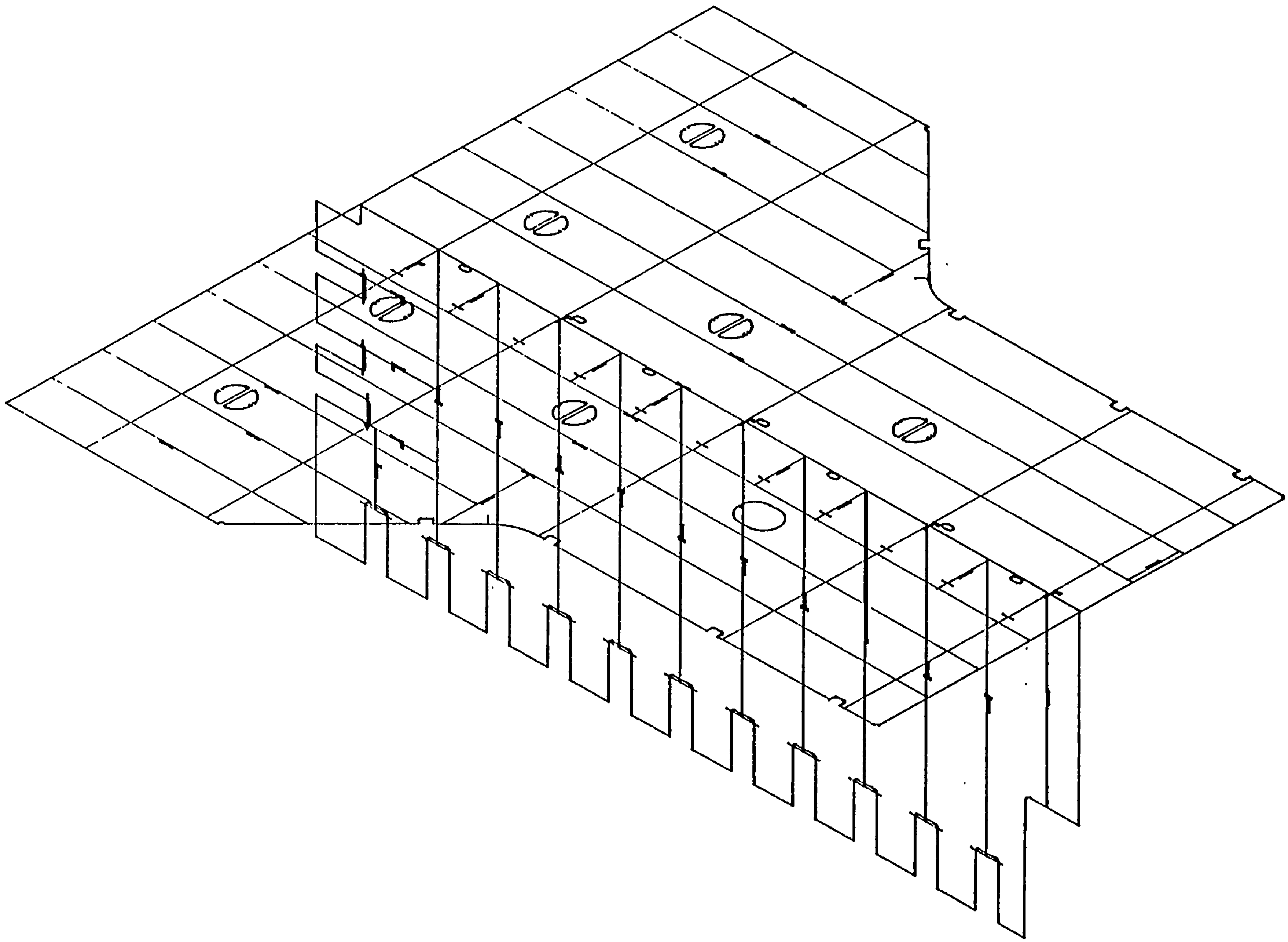


FLOOR MEMBER

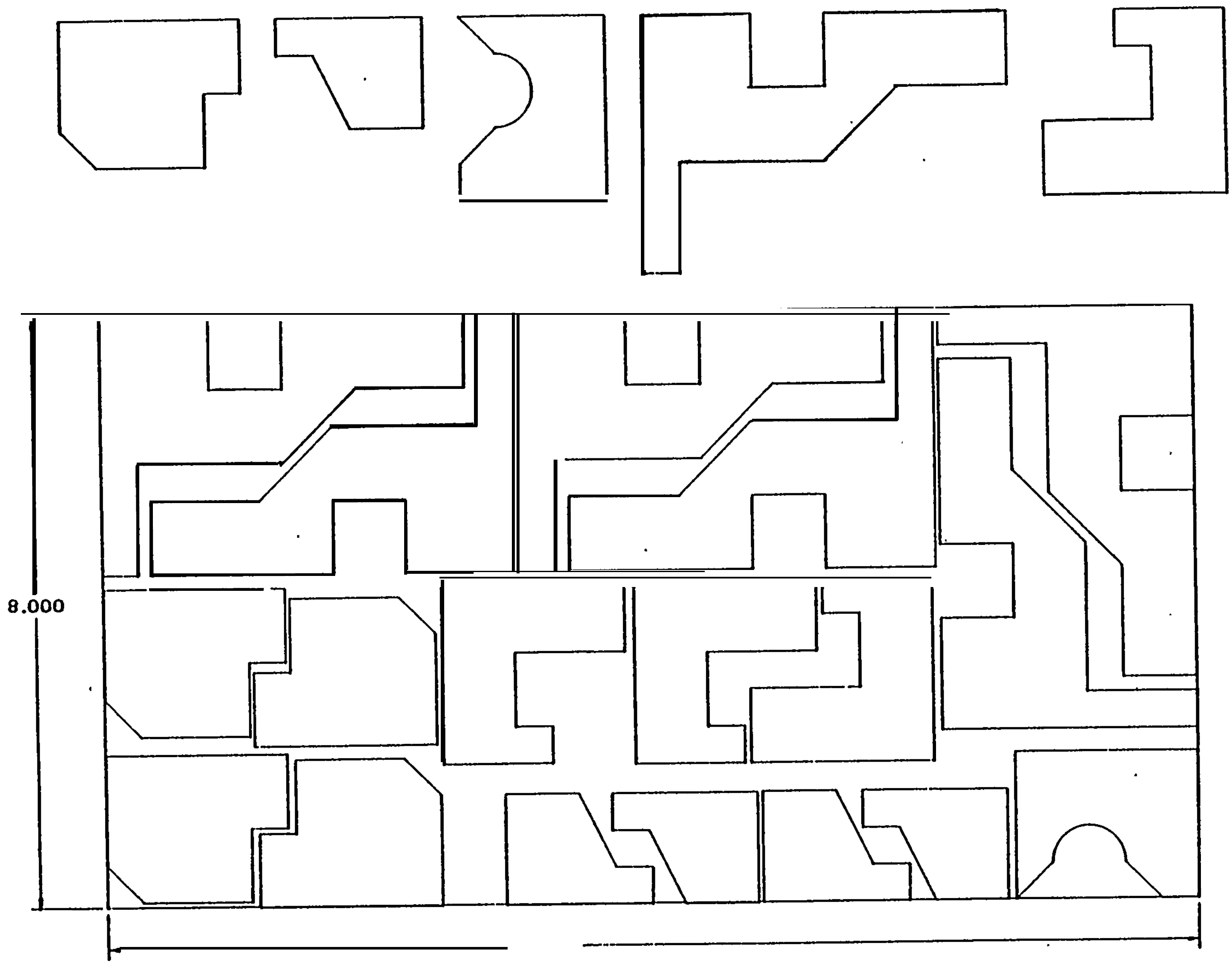








SOMETR C OF ASSEMBLY



PARTS NESTED ON CRT

USER REQUIREMENTS FOR THE NEWPORT NEWS INTERACTIVE PIPE DESIGN SYSTEM (RAPID)

Patrick J. Kelly
and
Patrick W. Rourke
Newport News Shipbuilding and Dry Dock Company
Newport News, Virginia

As Supervisor of Manufacturing Computer Systems in the Production Computer Systems Department, Mr. Kelly is responsible for numerical control, production and inventory control. He has a B.S. degree in Physics from the University of Dayton and is currently studying for an M.B.A.

Mr. Rourke is in the Engineering Technical Department where he designed Newport News' CAPDAMS system, a computer aided piping design and manufacturing system.

1. SCOPE

We are in the middle of the programming phase of a mini-computer based project for improved piping design called RAPID.

Because RAPID has been presented at a number of REAPS and other industry meetings, I presume most of you have been exposed to it. Therefore, I will begin with just a brief overview of the project here.

2. OVERVIEW OF RAPID

Purpose

The purpose of the RAPID project is to develop a low cost system for the capture and error checking of ship piping design in order to produce manufacturing documents for the piping shop.

Hardware

The system being developed is based around a mini-computer and several design stations. Figure 1 illustrates the hardware configuration. Each design station consists of a large digitizing table and a graphics display screen. In use, the designer will scheme pipe in the conventional manner, and then take his pipe scheme to the computer, either in the form of a composite or arrangement drawing.

Menus

The drawing is layed down on the digitizer table. A command menu is also placed on the tablet. Like most interactive graphics systems, RAPID software is driven by commands issued by touching the digitizer to appropriate menu boxes. Figure 2 is a typical RAPID menu. The user alternates between touching menu commands and points on the drawing to input the pipe geometry to the mini-computer. The resulting geometry is stored on a small data base within the mini-computer.

Error Checking

From this data base extensive error checking can be invoked, and single line and double line plots can be produced by an on-line plotter. Various

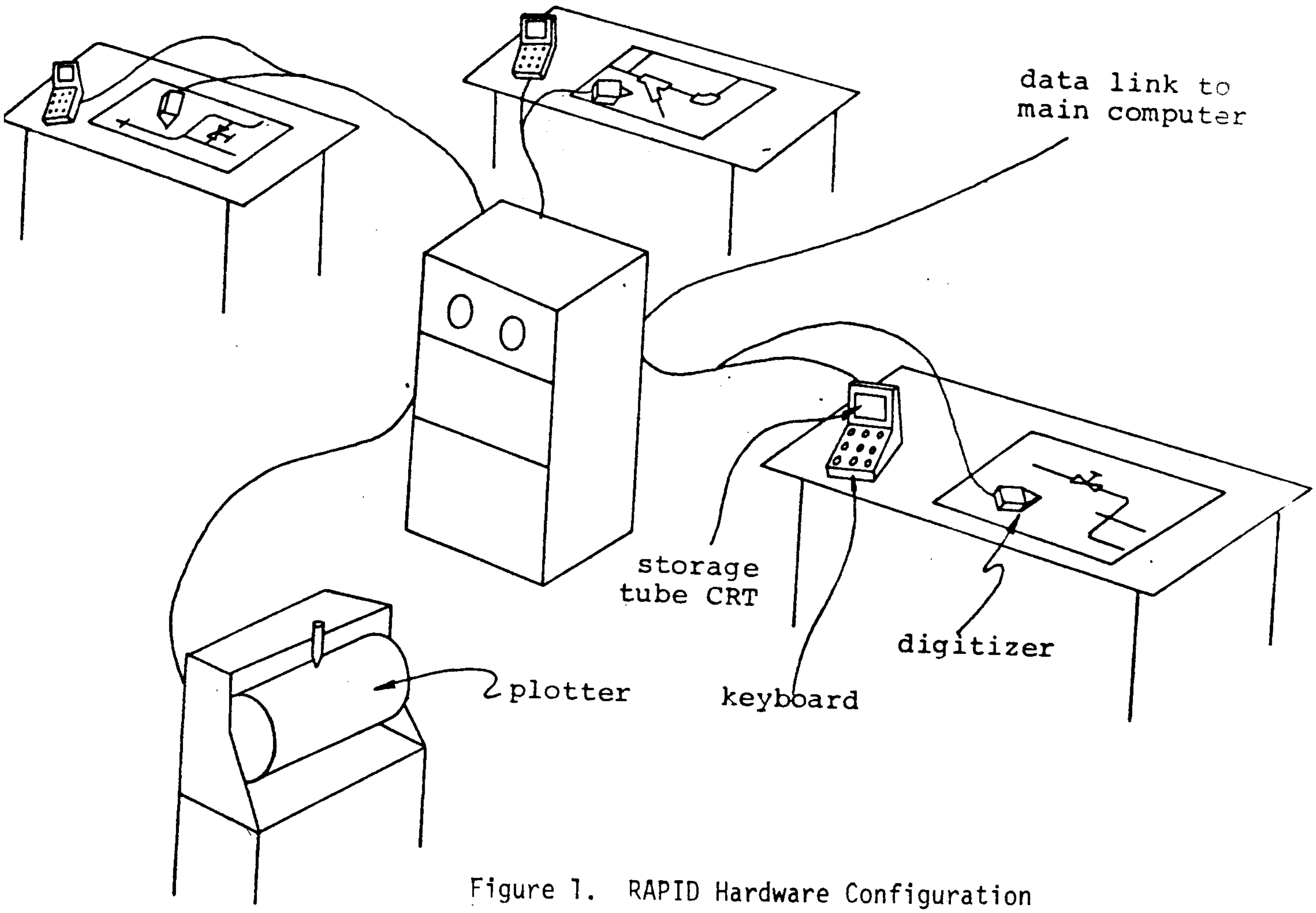


Figure 1. RAPID Hardware Configuration

Hardware	Vendor
Mini-computer 20 MByte disk 160 Kword memory TOTAL data management software	Varian V-76
Off-Line Storage Dual tape cartridge system	Kennedy
Plotter/Printer 22 inch wide	Varian
Digitizer 36 x 48 inch area Free Carsor	Samagraphics
Graphics Terminal Vector and character plotting Selective erase local zoom and pan	Hughes Aircraft

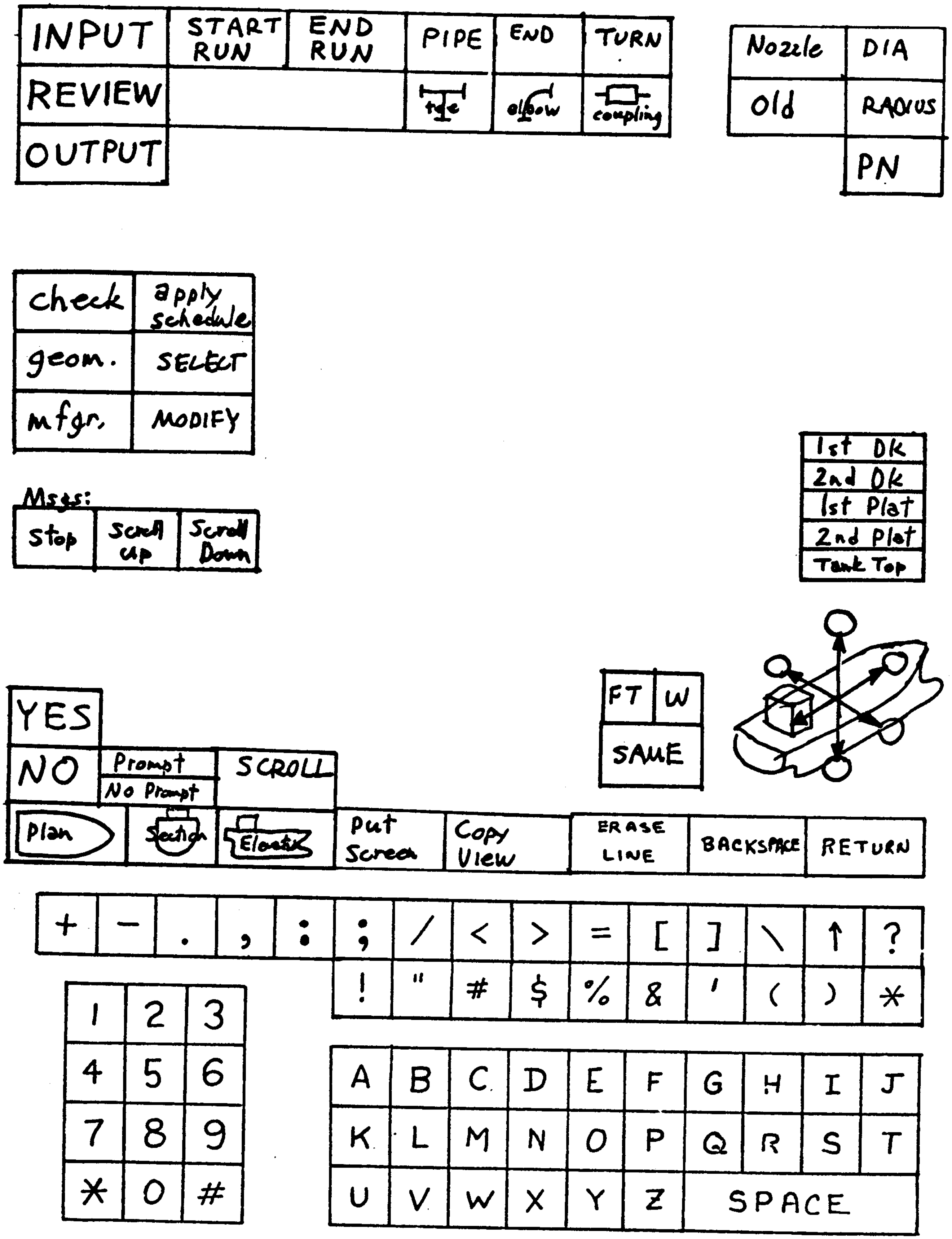


Figure 2. Typical Menu

design aids are being implemented, including automatic selection of fittings and some limited automatic correction of geometry errors.

Output

When the design has been completed, the user may request the production of pipe manufacturing instructions and material lists, and may have necessary data transferred by telephone to a main computer for interfacing to the yard's material control and production control systems and for more complex processing, such as production of weld joint maps. Figure 3 illustrates the communication between the various databases.

Status

This project is currently midway through development and is scheduled for delivery in March, 1978. At that time a demonstration workshop for interested individuals from the industry will be held at Newport News.

Summary

Input to RAPID allows users to:

- Define the geometry of pipe runs in a fast natural language
- Define decision rules for the selection of components
- Define the product structure (assemblies, subassemblies, etc.) associated with piping
- Define plots with arbitrary scales and viewing directions, and optional interactive labelling and dimensioning.

Processing allows users to:

- Apply decision rules to input pipe geometry and automatically select specific piping components as appropriate
- Check for design errors by testing pipe geometry against the known constraints of the pipe manufacturing facility
- Make modest changes in the pipe geometry to eliminate errors.

RAPID produces these items for user selected collections of piping:

- Piping drawings, with labels and dimensions of input
- Material lists
- Pipe bending instructions
- Schematic (joint map) drawings.

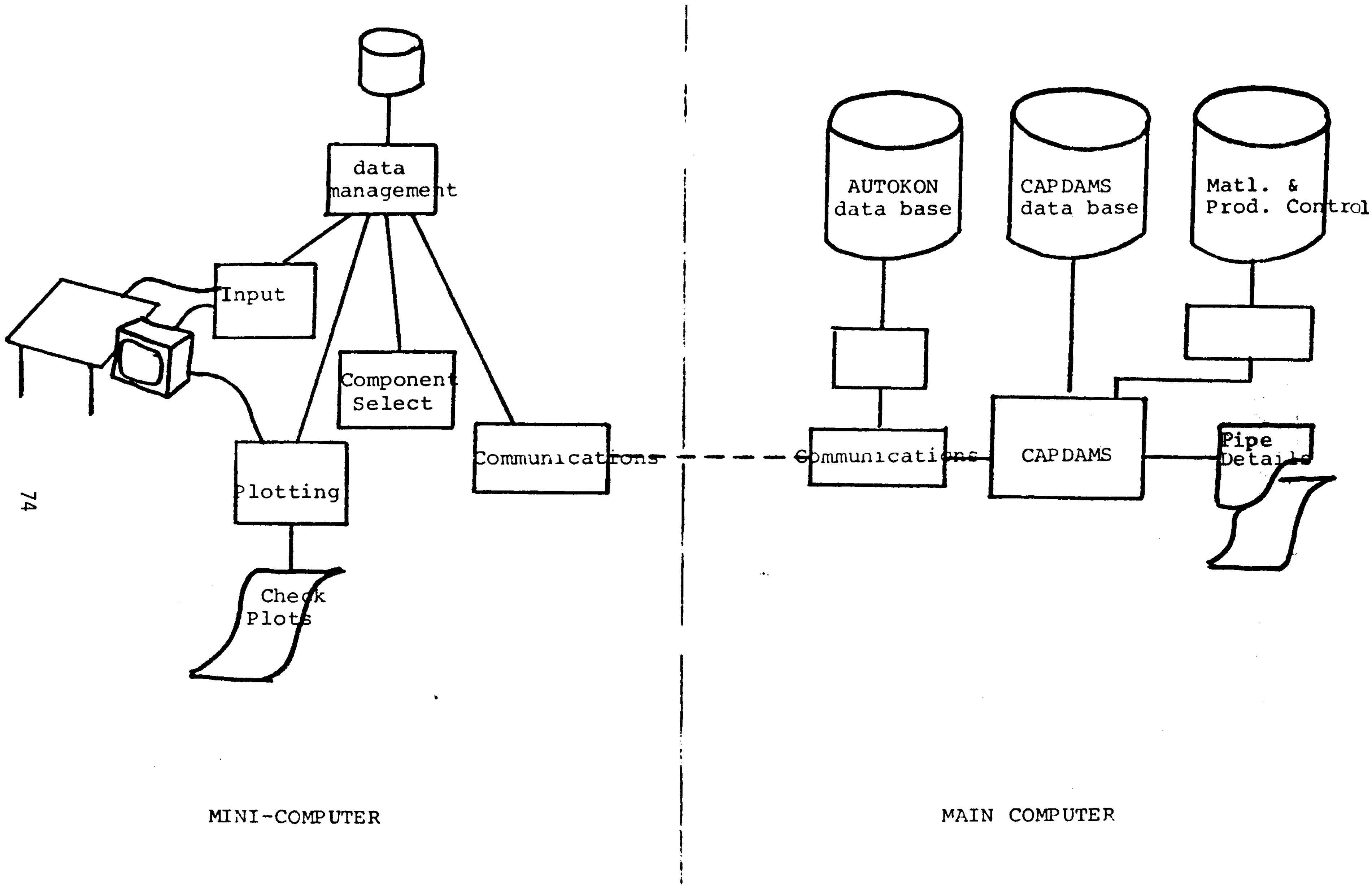


Figure 3. Database Interfaces

3. USER REQUIREMENTS

At this point I would like to cover the major user requirements that guided the design of the system. General requirements included software portability since this software should be readily usable by other yards on other computers at a relatively small conversion cost. A high degree of portability has been achieved by coding all programs in a subset of FORTRAN IV which includes non-ANSI standard features that are widely available or substitutable by subroutine calls. The language translator portion of the system has been converted from the Honeywell 6000 36-bit machine on which it was initially developed to the Varian V-76 16-bit machine in less than 20 man-hours. Conversion time of other modules is expected to be comparable.

The system also must be adaptable to other yard's requirements. Obvious programming techniques, such as variable field sizes, program modularity and segmentation are being used to make the software adaptable to other requirements with little extra effort. Some features (for example, the stand-alone production of pipe details) have been added to the design at the request of the User Review Group who felt certain features such as this one would make the system more quickly adaptable to other yard's environments.

Low cost is also an overriding concern and dictated the minicomputer hardware approach.

The ability to expand the software in the future overlaps somewhat with the other requirements. To readily expand from one to four stations, add modules and new programs, etc., are easy to accomplish since the system is modular and runs under a standard version of VARIAN's computer operating system.

The system also allows working with multiple piping systems at the same time by different designers at different stations without files becoming mixed up and without all files continuously on-line.

The efficiency with which the system handles changes and revisions is difficult to estimate since there are so many points where the designer can stop his work, make changes, call up other drawings, etc. The system is

flexible in allowing changes by the designer.

Approval and release controls mimic conventional drawing controls by using passwords, log-on identification sequences and recording of who made what change to the database and when it occurred.

4. OPTIONS

After identifying our requirements, the first thing we did was conduct a make/buy study. The options available were:

(a) Purchase a packaged hardware/software system from one of the vendors of interactive graphics systems and modify it or have it modified for our needs.

(b) Develop software from scratch, using a portable higher level language (such as FORTRAN) and a standardized data base manager, and implement a mini-computer.

(c) Develop a hybrid system consisting of a packaged graphics system, optimized for graphics speed, tied to a minicomputer of our choice running generalized data base software to meet our data base flexibility requirements. Hardware costs prohibited this alternative, however.

(d) Write programs in a high level language and implement them in a time-shared mode on large computers.

For most yards the last option is attractive because it requires minimal expenditures for new hardware. Unfortunately, the response requirements, especially with several design stations doing on-line plotting at the same time, can tie up a sizable portion of mainframe resources. The estimated time-sharing bill on our main-frame computer, for example, would have exceeded in six months the purchase price of a minicomputer capable of doing the job. Nevertheless, for users with light workloads, time-shared use of a main-frame may be the best solution, and the RAPID software to be delivered can be converted to operate in this manner.

We chose to go with a commercially available data management package, TOTAL, and develop our own interactive graphics software, rather than take a packaged interactive graphics system and modify its data base to meet our needs. Commercially available data management software is very good in terms of flexibility, reduction of programming effort, and backup and recovery control. Commercial data management software is also considerably slower than packaged graphics systems which use specialized data structures optimized for plotting.

Data Base Size

The total size of the piping data base for a design activity engaged in the design of several ships, including pipe and hull geometry and piping catalog information, is estimated at 200 million bytes. Although on-line disk storage is dropping substantially in price, this size is beyond the RAPID hardware cost, targeted at $100K.

We searched without success for a generalized data base management system which would be capable of selectively loading portions of the total data base. Not finding such software, we adopted a strategy which defines a master on-line data base, and stores data off-line in files. Data is selectively loaded into the on-line data base as needed. Most of the RAPID application programs operate on this master data base unaware of the fact that data originated from different files. A penalty is that it takes more time to load data onto the data base since it must be reformatted each time. We are expecting a two-minute format and load time for a typical piping drawing file, which we consider acceptable.

Response Time

The packaged graphics systems go to considerable lengths to design their data base software, and sometimes even hardware, for fast drawing of pictures. After some study, we set a limit of no more than 20 seconds to draw a typical piping view on a CRT screen. We knew that some package systems could beat this by a factor of eight, but we felt that 20 seconds was acceptable for the ship design environment.

A benchmark computer program was developed which tested the ability of a minicomputer and data base management software to retrieve data at a rate sufficient to meet the 20 second limit. Minicomputer vendors were asked to run this benchmark, and the final selection, a Varian V-76 with TOTAL data base software, was heavily influenced by the benchmark.

One of the original objectives of using a generalized data base manager had been to avoid redundant information storage. In order to meet the plotting response requirement, however, it was necessary to go to a partially redundant data structure in which separate records were kept just for plotting.

In a digitizer-based system the computer must be able to identify items as they are pointed out. This means that the computer must be able to search its data base on the basis of 3-D locations in space. Further, it is essential that the computer be able to respond rapidly, say within two seconds, to a digitizer touchdown.

Associative type data base software might meet this requirement, but this capability is beyond presently available standardized data base software. Our approach was to take an in-house developed bit-oriented 3-D indexing technique and implement it in FORTRAN as an outside index into the slower generalized data base, as illustrated in Figure 4.

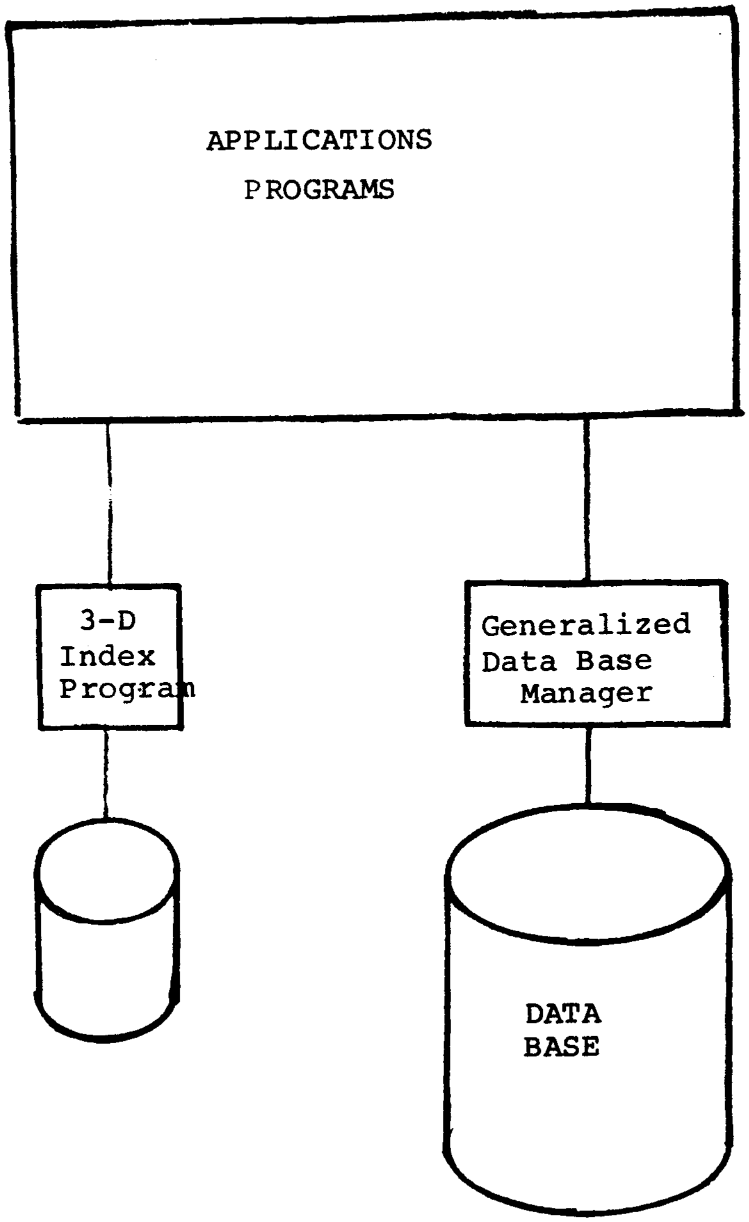


Figure 4. Indexing the Generalized Data Base

HIERARCHICAL APPLICATION OF COMPUTERS

FOR AN AUTOMATED PIPE SHOP

Hirohiko Aya
Mitsui Engineering and Shipbuilding Co., Ltd.
Tokyo, Japan

As General Manager of the Systems Project Department, Mr. Aya is responsible for planning and coordinating corporate systems development projects. His past experience includes structural engineering in ship design and the development of MES'S computer network.

Mr. Aya is a past chairman of Japan's GUIDE/SHARE Group (1975-6).

1. Introduction

As computer technology advances, the cost of automation is reduced. Recently, the technology of integrated circuits has developed rapidly, and the appearance of the micro-processor has become a center of attraction. It is expected that this will bring new possibilities for CAD/CAM. At the same time, the business environment of the shipbuilding industry has been changing rapidly. We must cope with the versality of production. In this new environment, efforts at further systems development are being made steadily. I will discuss the present status and new possibilities for automation.

Computer utilization of the Mitsui Engineering and Shipbuilding Company (MES) has been characterized by forming a link in the chain of management improvement programs.

Computerization of the piping job is one of the most important problems to be overcome in modernizing a shipyard. To sol ve this problem, in 1972 MES developed and implemented the semi-automated pipe fabricating shop systern ("MAPS") at the Chiba Shipyard.

2. Objectives and Implementation of the "MAPS" system

2.1. Present Status

"MAPS" was implemented at Chiba Shipyard in 1972. Its basic objective was to increase productivity and reduce costs .

"MAPS" consists of two subsystems. One furnishes the full numerical information required for fabrication of various kinds of pipes in the pipe shops . The other is an automated pipe fabricating system operated by numerical information cards, which does not require any experience or judgment by pipe workers.

(a) Numerical Information System (Software of "MAPS" System)
In the numerical information system, values of coordinates are put

into the computer from pipe arrangement drawings by reading start point, bending points and end points, and also branch points if necessary. Piping specifications, such as materials, working pressure, working temperature, types of fittings, coating, painting, testing, outfitting schedule and limitations of processing machines are also put into the computer in similar procedures. Then, necessary cards for numerical control of the machine and information for production control and material control are punched or printed out.

(b) Automated Pipe Fabricating System (Hardware of "MAPS" System)
Fundamental concepts in developing the new system were:

- Line production with practical automation
- Numerical control
- A constitutional improvement in conversion of worker into operator.

In the "MAPS" system, we succeeded in direct cost reduction during the past five years. It has resulted in a 60 percent reduction in man-hours covering 70 percent of the pipe fabricating jobs.

Through this experience, we have found these secondary but essential effects:

- Increase in accuracy resulted in cost reduction in the fitting stage . after fabrication
- Reduction in faulty fabrication made the production line stable.

As a result, more part programmers are required.

2.2. Graphic Piping System

As expected computer graphics is one of the most powerful means to promote rationalization of NC data processing. Nevertheless, because of high expense in hardware and difficulty in developing application software, practical use was delayed. In order to solve these problems, we have developed a new computer graphic system, the "GRAPH MINI" system. Some of the features of this system are:

- **Adoption of digital techniques**
- New hardware architecture with a dedicated graphic processor
- Adoption of a virtual memory system to a minicomputer.

Based on the fundamental techniques mentioned above, practicability and cost performance were thoroughly pursued. We have connected a general purpose, large computer as a host computer through a data communication cable to a dedicated minicomputer, connected to the graphic display device as an intelligent terminal. In this system, conversational pattern process function was shifted to the minicomputer. Therefore, the host computer can devote itself to executing problem processes and problem oriented data base manipulation. The basic software of "GRAPH MINI" was implemented by MES under commission from the Information-technology Promotion Agency (1.P.A.).

The graphic NC system for steel plate flame cutting, the so called "GNC" system, is the first practical application of "GRAPH MINI". It was implemented at Chiba Shipyard in 1975. In the "GNC" system, we realized high working efficiency with low cost by exploiting a mini-based turnkey system. The GNC system has saved 60 to 70 percent of man-power as compared with a conventional system.

We started the development of a Graphic Piping System, the "GPS" system, in 1975.

In our company, piping jobs are very common not only in the shipbuilding yard but also in the chemical plant shop and in energy plant construetion. The feasibility study to develop the graphic piping system was carried out in advance, and the integration of this CAD project was a success.

At present, the first release of the "GPS" system has been implemented. This release is intended for chemical plant use. The second release will be completed by the end of 1977. At this time, the function of the Numerical Information System of "MAPS" will be added to the GPS system. The new functions are shown in Fig. 1.

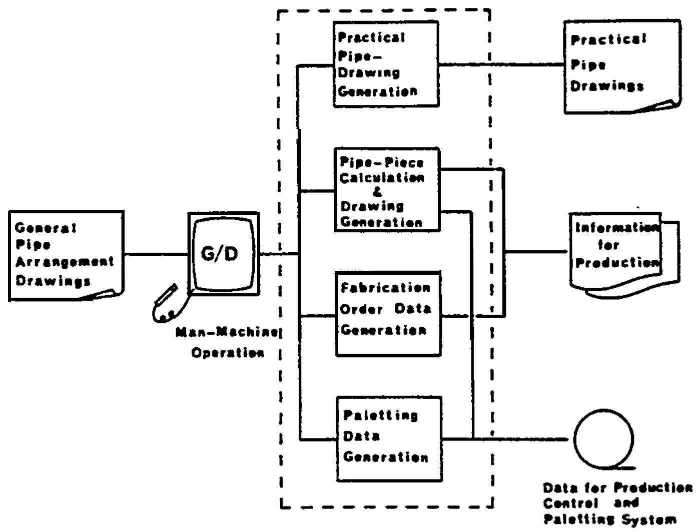


Fig. 1. Function of GPS System

	Development Start (Main Computer)	Technical Target	Company's Effectiveness
1st step	1971-72 1973 (IBM 370-155)	•Centralization •No-conversion	•Down time cost of computer (20%)
2nd step	1973-75 1976 (IBM 370-168)	•Multi operation •Graphics •Factory data gathering •Minicomputer	- Labor saving •Increasing engineering power
3rd step	1976-78 1979 (IBM 3033)	•Computer network •Corporate data base •Micro processor	〃 Total cost reduction •Management efficiency improvement

Fig. 2. MACSNET Long Range Plan

The “GNC” and “GPS” systems will coexist in one minicomputer. The “GPS” system is expected to reduce by 50 percent the number of part programmers and draftsmen in the production design stage.

3.' Hierarchical Application of Computers

3.1. MES’S “MACSNET” Plan

In 1970, we faced increased expense for computer usage and input data preparation. To solve this problem, we projected a long range plan for hierarchical computer network development and called this plan “MACSNET”.

The basic objective of “MACSNET” was to create the environment to select the optimum computer hardware for every type of advanced application. In order to obtain the maximum effect with minimum risk, “MACSNET” was divided into three steps as shown in Fig. 2.

The second step of this plan has been completed, and the third step is being developed currently.

3.2. Distributed Computing for Automated Pipe Shop

The basic requirements of control equipment for a more advanced automated pipe shop are:

- Low cost
- Easy use
- High reliability
- Easy maintenance
- Flexibility
- Communicability

The state of the art of micro processor technology has already satisfied these requirements. It gives evidence of greater potentiality when the integration of individual control of automated equipment and semi-automated equipment is possible in the commercial base. Fig. 3 shows an example of the future plan.

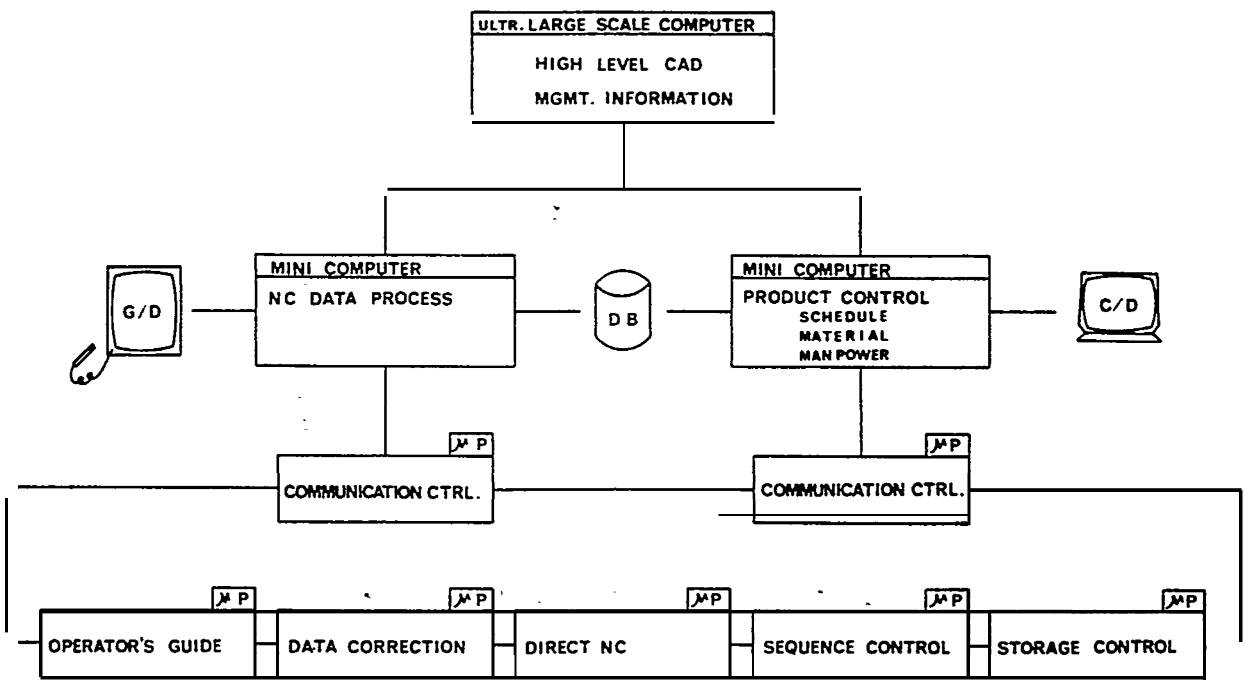


Fig. 3. Example of the Future P1an of Automated Pipe Shop

Great changes in the quality of utilized computer technology will be necessary so as to realize the integrated manufacturing system. They are:

(a) Computer architecture design

- Function sharing
- Reliability and flexibility
- Cost reduction using minicomputers and micro processors

(b) New peripherals

- Interactive graphics display
- Factory data gathering device

(c) Communication

- In house: data high way
- Computer network

(d) Software

- Programming support system for distributed computing
- Trade-off software and hardware
- Standardization of aplication

4. Conclusion

System development is now proceeding in line with the improvement program of management. Increasing computerization development of the graphic piping system in the shipyard is being promoted to meet the new business environment in chemical and energy plant construction. The technical challenges for the future automated pipe shop are:

- More flexible control using micro processor technology
- More adaptable production using interactive computer graphics.

The state of the art of computer technology plays an important role in promoting further computerization of the pipe shop. A long term approach is necessary. Although the development now proceeding is still incomplete, I have described its outline. I appreciate your frank criticism. My thanks to the many colleagues with whom I have discussed this program.

CONSIDERATIONS FOR AN AUTOMATED

PIPE FABRICATION FACILITY

Ollie H. Gatlin
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New Orleans, Louisiana

Mr. Gatlin manages Avondale’s plant engineering and maintenance activities. Before joining Avondale, he was a Lieutenant Colonel with the Army Corps oF Engineers. In this capacity, he was a facilities and equipment plant engineer in the Panama Canal Zone, a nuclear weapons officer, and a research electronic fire control engineer.

Mr. Gatlin has a Civil Engineering degree from Northwestern University of Florida and a Mechanical Engineering degree from the University of Alabama.

Approximately two years ago Avondale Shipyards, Inc., submitted a proposal to the U.S. Maritime Administration on the development of a semi-automatic pipe fabricating facility. This proposal was accepted and, since that time, we have been conducting an in-depth study of the subject.

Fabrication cost of ship piping systems is of a magnitude worthy of study, since it is roughly equal to one-fourth of the total hull cost of a ship. For a 176,000 DWT tanker, this amounts to approximately 200,000 man-hours of production. It is our opinion that through automation a percentage of the required man-hours can be reduced in the following functions: handling (65%), fitting (55%), welding (30%), cleaning (75%) and coating (85%). These percentages are based on LASH vessel construction since all of our original data is applicable to this series of ships. An overall percentage reduction in fabrication man-hours equates to approximately 37.5 percent per shipset. Therefore, it is conceivable that we could have fabricated each piping system for 25,000 man-hours as compared to our actual cost of 40,000 man-hours.

On vessels presently under construction at Avondale, savings through automation could be as high as 30,000 man-hours, or in excess of $420,000 per vessel, and we can complete three such ships per year plus five ships of the LASH type.

Our study has been conducted at our Main Pipe Shop and utilizes manual fitting, welding and burning as a base along with our original shop layout and flow diagram. We originally had a production capacity of 50 to 55 spool pieces per day with a complement of 76 people in this department. Basic changes which we have accomplished during this study, such as wire-feed welding in lieu of stock welding, provision of a cutting station, installation of contour cutting machines and utilization of a limited amount of turning and manipulation equipment, have increased our production to 60 to 65 spool pieces per day.

Before getting into the subject at hand, I would like to point out what pipe fabrication systems exist as the state of the art.

There are several equipment manufacturers in the world today who have

developed and are marketing automated pipe fabrication equipment for the shipbuilding and pipe fabrication industries.

Japan has two major manufacturers. First, is the Ishikawajima-Harima Heavy Industries Co., Ltd., or IHI, system which is very efficient, but is limited as to pipe diameter and to processing of steel pipe only. It provides storing, marking, flange fitting and welding, cutting, bending, loading and transferring capabilities.

Second, is the Mitsui Engineering and Shipbuilding Co. which has an existing system, called MAPS, similar to the IHI system, but is also limited as to pipe diameters and does not provide for alloy material. However, we feel Mitsui could provide for the complete shop, and they have done some outstanding planning and development work in this area.

IHI and Mitsui, as well as Hitachi Shipbuilding Co., Ltd., can provide software packages to support the required degree of automated hardware and material control. Mitsui's software package is very sophisticated and seems to provide more desirable features than any other existing system. It also has all capabilities for engineering requirements, including preparation of detail drawings. Therefore, it appears to be Mitsui's major marketing item.

The Maritime Administration has awarded a feasibility contract to Newport News shipbuilding and Drydock Co. for development of a software package which would provide engineering, including digitizing, in support of an automated design system. Avondale, in conjunction with Newport News, is studying the feasibility of integrating this system with the hardware system we are attempting to develop.

In Germany, oxytechnik has the capability to provide complete automated systems except for branch welding, sub-assembly type work and a software package necessary for engineering and control of equipment. This manufacturer has been extremely energetic in adapting to and meeting the requirement of, various types of pipe fabrication processes. Kockums Shipbuilding Company has developed an excellent program nicknamed “system Q" and "Steer Bear”, for use with the Oxytechnik system within their own pipe fabrication shops for production scheduling, engineering and material and machine control.

Mecaval International, in France, has developed a pipe shop system but it is limited to cutting, flange welding and numerically controlled bending and conveying equipment. St. Nazzair Shipyards has developed an outstanding fitting and welding system to support this Mecaval system.

In Sweden, ESAB systems have been limited to flange welding machines and manipulators. However, ESAB has developed exceptional welding equipment in the past and is presently studying the feasibility of utilizing their robot units in pipe welding. Preliminary data on this equipment indicate possibilities in this area.

Here in the United States, some welding technology has been developed along with pipe manipulators and turning devices.

We have visited many companies in the United States, and a few in Europe which are involved in processing pipe for chemical plants, oil refineries and pipe fabricating companies. In general, all pipe production we have witnessed is as inadequate, or backward, as it is in the shipbuilding industry, with some noteworthy exceptions.

We have concluded that there is not a single total automatic, or semi-automatic, pipe fabricating system available in the world today. Yet, most of the machines required for such systems are available in Europe, Japan, and the United States.

The primary objective of our study is to design a cost effective and automatic method of fabricating pipe which will reduce the labor, material handling, storage space and required fabrication area.

Such a facility for the shipbuilding industry must be designed to handle 1-1/2″ through 24″ diameter pipe and all ASTM Class I schedules and alloys of pipe used in shipboard systems. The facility must be versatile and equipped to handle repair jobs and specialty items, as well as new vessel piping systems.

The following functions represent a pipe fabricating system which can be

implemented along with certified procedures where necessary, either in part or as an entire system at any major shipyard.

1. Rather than random stacking and storage experienced in many areas, a systematic rack storage and locator system for all types of pipe, in sizes 1-1/2″ through 24″ must be established. The storage racks must provide for loading, selecting and off-loading onto a transfer system automatically.

2. A sorting and automatic feed system must be installed at the pipe storage rack so that an operator can automatically select pipe from the rack, load it onto a conveying system and convey it to the work station.

3. The automatic conveying system, for movement of pipe from one work station to another, must be equipped with an automatic unloading device at each station and a reserve area to hold pipe for each machine at the specific station.

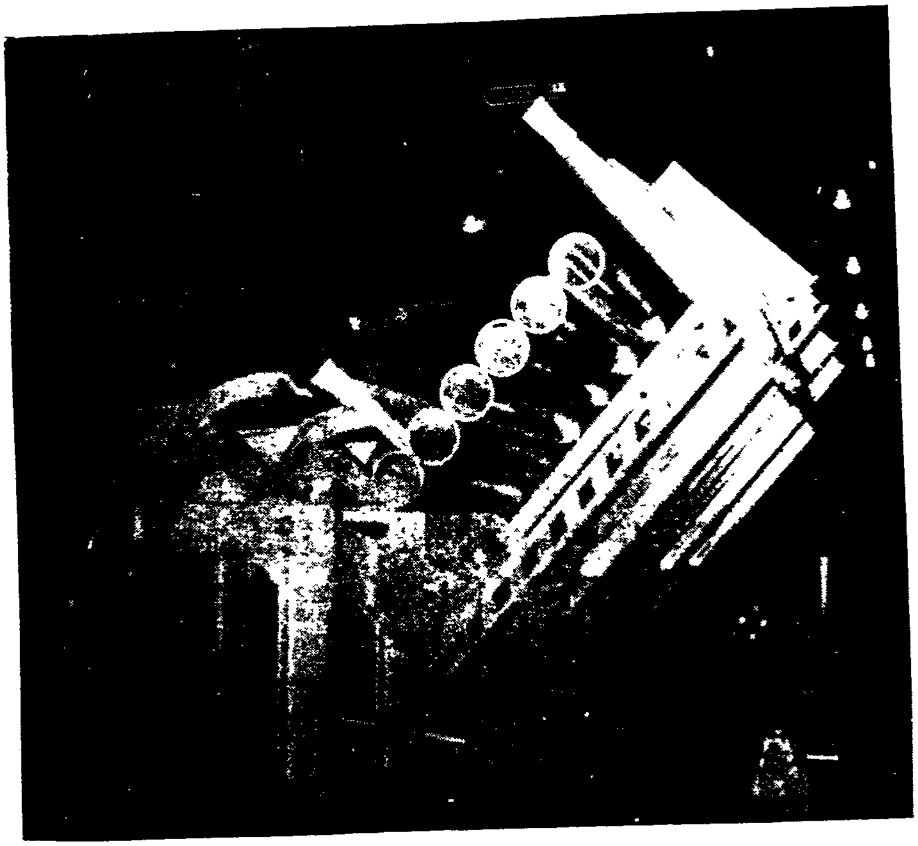
4. A measuring system must be installed to automatically measure pipe for cutting to length, locating holes and other layout requirements.

5. A system must be furnished to mark each component of the assembly with the specific part number as identified on the production drawings.

6. Cutting and end preparation machines must be provided. This function is extremely important since, in order to obtain good welding results, the use of machine cutting is an absolute necessity. At this point, all scrap must be conveyed out of the shop area by means of conveyors or other handling equipment.

7. An automatic flange fitting and welding device must be installed and have the capability to process the pipe alloy mix, as well as, select the flange, orient it properly, tack it and weld both inside and out.

8. Adequate numerically controlled bending equipment must be provided capable of two-diameter bending for up to schedule 80 pipe, 8 inches in diameter. Adequate bending facilities for larger pipe will depend upon the



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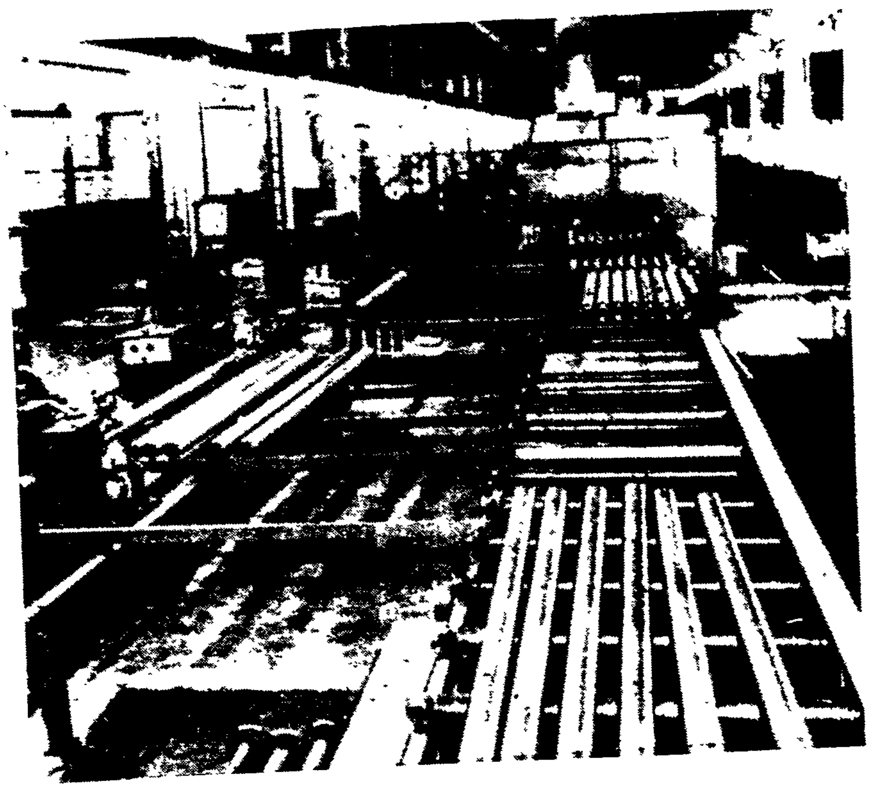

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number of ship systems for which larger pipe is required. It can be either hot bending or vibratory bending. An important function of this bending equipment, in addition to the two diameter bends for pipe up to 8 inch diameter, is the capability of being automatically fed and bent with flanges already welded on both ends.

At the present time, most bending machine manufacturers located in the United States appear not to be interested in designing equipment, or modifying existing equipment, to accommodate flanged pipe to be bent.

9. We must select the various types of welding equipment which will be required to process the mix of pipe going through the system, provide rolling devices for welding of straight pipe and incorporate automatic loading and unloading mechanisms as well. The development of semi-automatic welding devices for sub-assembly and assembly areas is a desirable procedure, along with certified welding procedures.

10. Assembly areas, in almost all establishments we visited, were the most labor dense and backward in terms of automation. In fact, in many shops, we wondered why management has not asked, "Why can't we improve this area a little?". Here manipulator fixtures must be designed so that assembly of Pipe sections can be processed in an effective manner. Manipulators are to be fitted with semi-automatic loading and unloading devices and must be capable of positioning the main body of pipe into position so that fitting and one pass welding can be accomplished. The welding devices should be selected and developed concurrently with the manipulator fixtures for this function.

11. Determine the configuration and quantity of X-Ray booths and equipment required to support the maximum work load of this work station and provide handling equipment required for loading, manipulating, and unloading the X-Ray booths.

12. provide for a semi-automatic internal and external blasting and coating system for pipe. A by-pass would also be provided so that all full length pipe, which does not require further processing, will be channeled directly to the assembly area.

13. Designate a specialty area for the fabrication of the inevitable "exception". We must select machines, tools and handling equipment for processing specialty items of a configuration and volume not suitable for automatic and semi-automatic processing. The specialty area will be situated so that it is accessible to the automatic conveying system. Generally, work in this area will be accomplished by hand.

14. We must provide a final product storage system where the fabricated pipe and specialty items can be palletized and stored in a racking system, in usage order, until required. A locator system, to be used for accountability and retrieval, should control the storage function. on.

15. Transportation and handling equipment must be provided for selection, load-out and delivery of fabricated pipe to the installation site.

16. The computer software package must be developed to support this fabrication shop, as our investigation has revealed that all man-hour savings, to be experienced by an automated system, can be completely offset by a major increase in the Engineering Staff necessary to provide the drawings and other data in a timely manner. Therefore, a computer software package must be developed to operate this system and have the capability of preparing pipe detail drawings. As these drawings are being prepared, the program should select required information from data banks which would allow the concurrent preparation of bills of material, shop production schedules, material flow schedules, cutting lists, assembly marking and bending data, machine loading schedules, and final disposition and delivery schedules.

We envision the use of a mini-computer, supported by a primary computer, which could utilize a digitizer or some other method to design, update and revise the various parts of the system.

The software package must be in the form best suited to the specific facility and working methods of the particular system, such as the order card for numerically controlled equipment, tape for tape controlled equipment, and numerical list for other equipment and manual operation.

In conclusion, let me summarize by conveying to you what we at Avondale expect the cost of implementation will be, what we expect to gain from our proposed automated system, and what approach we anticipate taking.

Without a doubt the cost of this facility will not be cheap. A system as described would cost anywhere from 2 million to 5 million dollars dependent upon existing shop facilities and the size and type pipe to be processed.

With an investment of this magnitude we can expect at least two things:

1. An extremely efficient pipe fabrication shop capable of meeting required production schedules. The system we contemplate is designed to produce 150 pipe spools per day with a corresponding limited reduction of skilled shop manpower. We expect that production will increase from one spool per man per day to 2.3 spools per man per day, including blasting and coating.

It should be noted that since we are a non-union yard the reassignment of personnel does not present the associated contractural problems.

2. An extremely cost effective pipe fabrication shop. As indicated at the outset, an improvement in man-hour cost of 37.5% can be realized. However, with all functions of the system operating, a 50 to 55% reduction in production cost is easily attainable in even the smallest of automated facilities we have seen.

Our approach must include the establishment of the required work stations and the development of the required welding techniques and procedures. Quite a bit of this has been achieved in our welding laboratory. Implementation in our production area is being accomplished as these systems and procedures are approved by the regulatory agencies.

We must be open-minded concerning old techniques which could lend themselves to automation and improve cost. One such item is the use of Van Sloan flanges with cold extrusions or “cold-necking” of steel, stainless steel, and copper nickel pipe in order to reduce the number of tees, weldelets, and welding otherwise required.

Finally, we must overcome a negative attitude toward change which would be intolerable. Fortunately, at Avondale our Pipe Shop personnel provide the prime stimulus in our improvement program. It is this motivation, this impetus on the part of management, the engineering staff and the production department that is necessary to make an automated system work, regardless of the numerous problems which are to be encountered.

	PROPOSED	EXISTING
I. PIPE STORAGE RACK		
Cycle Time	1.5 Min.	10 Min.
Input Data		
1. Pipe Diameter		
2. Pipe Thickness		
II. AUTO PUNCHING.		
Cycle Time	2 Min.	5Min.
Input Data		
Punching Position		
Punching Letters		
III. AUTO MARKING		
Cycle Time	2 Min.	10 Min.
Input Data		
Pipe Diameter		
Marking Positions		
IV. AUTO CUTTING		
Cycle Time	2 Min.	10 Min.
Input Data		
pipe Diameter		
Cutting Position		
Cutting Shapes		
Sorting Destinations		
V. AUTO FLANGE FITTING/WELD		
Cycle Time (Includ Weld)	5 Min.	25 Min.
Input Data		
Position of Flange Holes		
Welding Space		
Tack Welding Conditions		
Welding Conditions		
Sorting Destinations		

	PROPOSED	EXISTING
VI. BUTT WELDING		
Cycle Time	6 Min.	30 Min.
Input Data		
Fitting Position		
Welding Conditions		
VII. BEVEL CUTTING		
Cycle Time	4 Min.	10 Min.
Input Data		
Cutting Position		
Cutting Speed		
VIII. PIPE BENDING		
Cycle Time (2 Bent Pipe)	4.5 Min.	10Min.
Input Data		
Angles		
Planes		
Positions		
Flange Hole Pitch Diameter		
IX. BRANCH PIPE WELDING		
Cycle Time	10 Min.	30 Min.
Input Data		
Fitting Position		
Welding Conditions		
TOTAL:	**37 Min.**	140 Min.

NOTE: Samples taken on 4" Dia. Standard Pipe **.160 Wall**

WORK-PAC: WORK PLANNING AND CONTROL SYSTEM

Laurent C. Deschamps
SPAR Associates
Annapolis, Maryland

As President of SPAR Associates, a company specializing in computer applications for business and engineering, Mr. Deschamps has been involved with computer-aided ship design and production methods, planning, estimating and scheduling services, and ship structural analysis. SPAR Associates has served as consultants to a number of American and Canadian shipyards in implementing automated labor and material planning and control systems. Mr. Deschamps has also been a consultant to the U.S. Navy for structural analysis.

In the past, Mr. Deschamps was Director of Engineering for Corn-Code Corporation, a project engineer with Armstrong Cork Company and an instructor of computer programming.

He has his B.S. and M.S. degrees from Trinity College, Hartford, Connecticut.

INTRODUCTION

WORK-PAC, Work Planning and Control System, is a complete computer software package designed to improve shipyard labor planning and to monitor labor charges against planned estimates, measure job progress and give notice to both real and potential labor over-runs and schedule slippages.

WORK-PAC permits a ship repair/conversion or new construction project to be broken down into discrete work orders, which can be classified under any given set of work cost account categories: steel work; piping, electrical and machinery systems; outfit; design/drawing; and yard support services. To further facilitate labor scheduling and control, WORK-PAC allows these work orders to be assignable to specific ship zones and shop work centers. The input of planned manhours (with or without trade estimate detail) and scheduled start and finish dates and the actual manhours from timecards as applied to these work orders completes the planning feedback cycle that is tailored to shipyard operations.

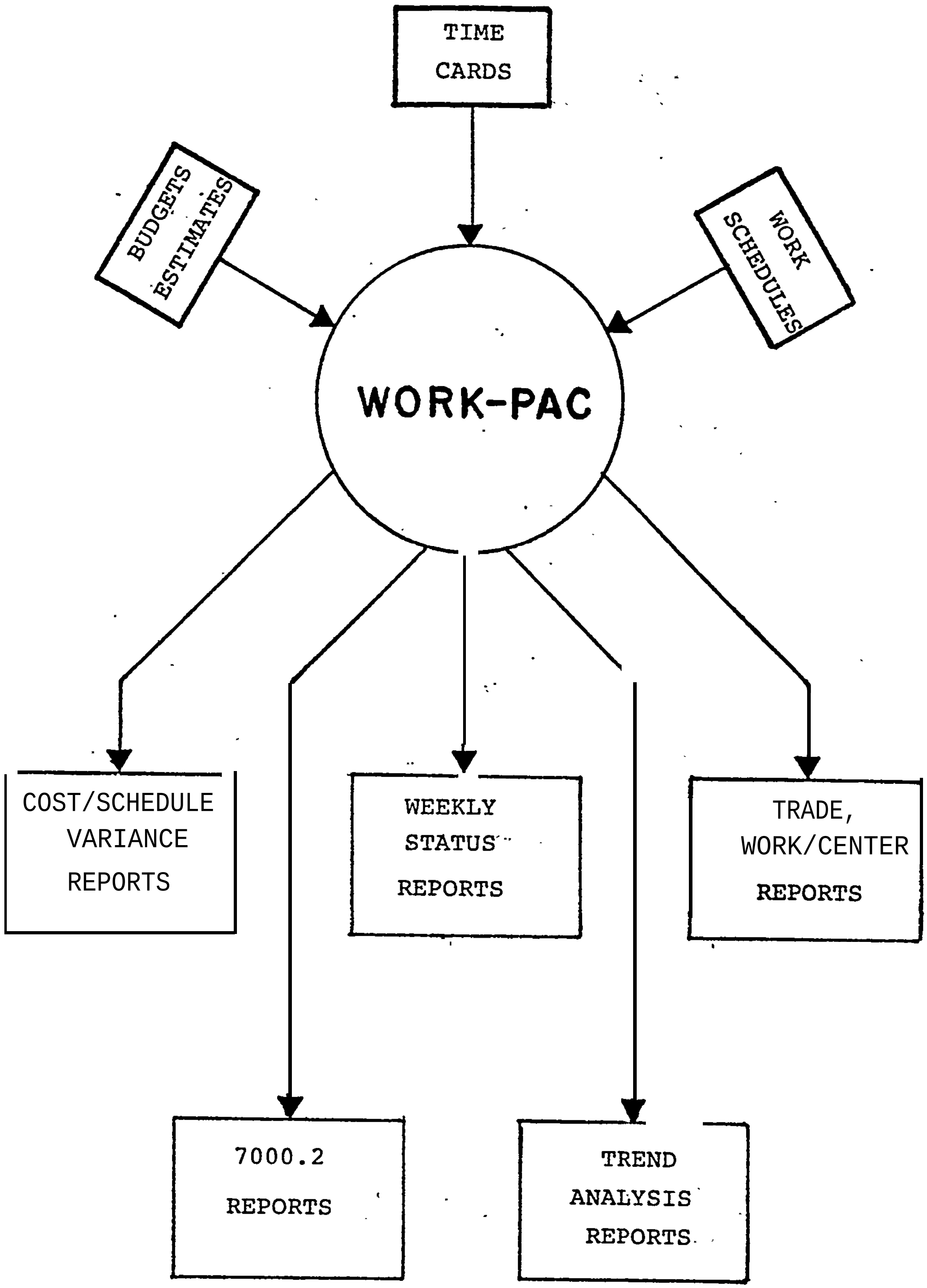
WORK-PAC accummulates labor charges by individual trade, differentiating between regular and premium manhours. In addition, a special WORK-PAC feature provides for separate accounting of job repair end re-work efforts as required.

WORK-PAC generates numerous reports and analyses for various. levels of the shipyard organization and at various levels of detail. WORK-PAC issues automatic warnings of data errors and signals areas of budget over-runs and/or schedule slippages early in the production cycle before they become critical and while they are still resolvable.

WORK-PAC represents many man-years of intensive development within active shipyard environments and responds to the practical problems of daily shipyard operations.

WORK-PAC is designed to operate in parallel with SPAR's Material Requirement Planning and Control System [MAT-PAC), a project scheduling (critical path method) system of the yard's choice, and SPAR'S Basic Ship Estimating and Budgeting System [ESTI-PAC].

WORK-PAC is written in standard ANSI FORTRAN IV, a computer programming language suitable for operation on most present-day computer Facilities, either in-house or remote timesharing.


TIME
CARDS
BUDGETS
ESTIMATES
WORK
SCHEDULES
WORK-PAC
COST/SCHEDULE
VARIANCE
REPORTS
WEEKLY
STATUS
REPORTS
TRADE,
WORK/CENTER
REPORTS
7000.2
REPORTS
TREND
ANALYSIS
REPORTS

WORK-PAC BENEFITS

The immediate benefits available from the use of WORk-PAC are summarized as follows:

a. Timely, accurate, and complete report information which is custom tailored For the given reader's level of interest and responsibility

b. Elimination of duplicated and oftentimes erroneous information by virtue of a common database accessible by various departments and levels of management

c. Complete flexibility in project work breakdown definition so that different job requirements and/or production procedures may be implemented quickly and easily

d. Convenience of modelling possible management decision alternatives with the capability to view resulting effects immediately

e. Immediate and automatic warning signals by WORK-PAC in numerous possible problem areas to provide management with increased lead-time to respond to bottlenecks and costly delays

f. Continuous and automated physical progress assessments et various levels of the project work breakdown structure

g. Continuous and automated projections of final total costs based upon WORK-PAC's assessments of past, current and expected future labor performance

h. Systematic storage of meaningful and complete historical production data available for immediate use in planning and estimating future projects

i. Software expandability into other application areas including direct hook-up with other software packages

j. Virtual machine independence to minimize possible conversion and software maintenance costs

k. High level of user confidence produced by WORK-PAC's numerous checks and edits of data entries and diagnostic messages

l. Ease in WORK-PAC usage as accomplished by considerable software design effort to minimize user input and data organization requirements

m. Software reliability as proved by four years of continued use within shipyards

GENERAL DESCRIPTION

ORGANIZATION CRITERIA

(1) WORK-PAC permitS definition of all authorized work and related resources, using whatever contract work breakdown structure [WBS] is appropriate for the given shipyard contract: now ship construction, ship repair/conversion, or non-ship commercial projects.

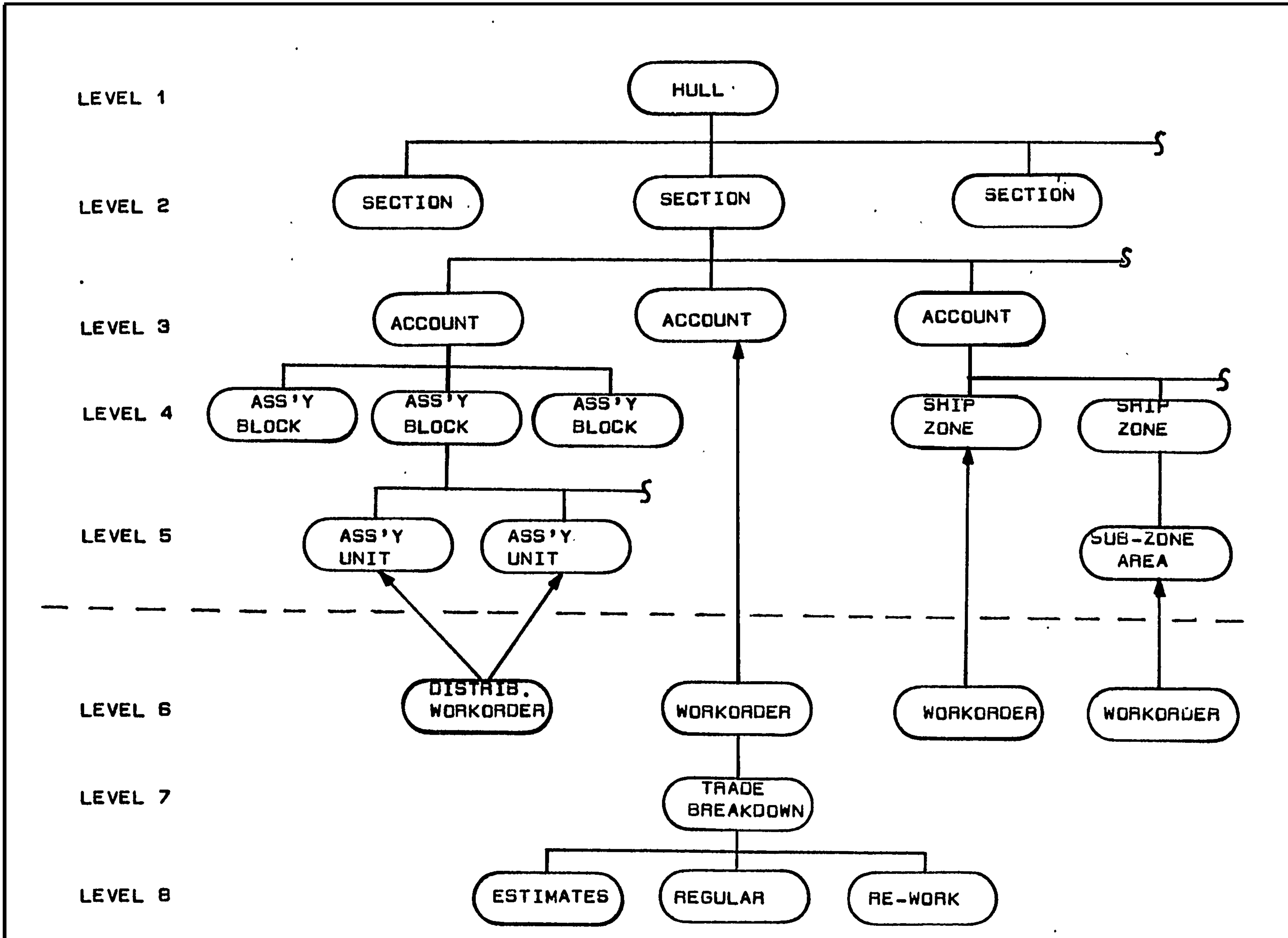
The primary work breakdown is the project cost accounts, which identify the various ship functional systems, yard services end support efforts. Cost accounts may be grouped into sections of similar account categories for more general summarizing capabilities. WORK-PAC also produces summary reports of the over-all project as well.

Below the cost account level of the WBS, WORK-PAC permits the development of two additional sub-levels for more detailed summery capability and for summarizing across appropriate cost accounts as needed. For steel work, major hull structural assemblies (blocks) may be defined and each broken down into individual steel units; these sub-levels are programmed under the expropriate fabrication, assembly, erection and on-ship welding cost accounts. Blocks and units may also be programmed for any pro-outfitting accounts if required.

For nom-steel work such as outfit, piping, electrical, end machinery cost accounts, WORK-PAC permits two levels of ship zones to be defined to facilitate the scheduling and resource loading of appropriate cost accounts. Zonaing can also be beneficial for future ship estimating.

WORK-PAC provides immediate means to summarize budget, planning, accummulating and projected costs and to determine automatically at any point in time the physical progress at, and across, any of the WBS levels. Summaries may also be generated within individual trade groups and/or chop work centers at and across any of the WBS levels.

(2) WORK-PAC permits easy identification of all internal organizational elements of the yard within the WBS, including steel work, outfit, piping, electrical and mechanical departments, yard services, engineering, planning and cost control, supervision, testing and quality control



WORK BREAKDOWN ACTIVITY STRUCTURE

efforts. WORK-PAC also fully provides summary and progress reporting at any shop work center and/or trade group.

[3] WORK-PAC fully integrates the yard's planning, scheduling, budgeting, work authorization and cost accumulation efforts as programmed for the WBS cost accounts, steel blocks and units, ship zones and shop work centers, trade groups, and individual work packages.

[4] WORK-PAC can be used equally to control various overhead efforts as may be identified either within the WBS of cost accounts for the contract or as programmed for a separate group of cost accounts to be budgeted and monitored independently.

[5] WORK-PAC integrates the contract product elements [various ship systems, for example) directly with the yard's Functional organization structure within the WBS. Cost accounts may be sectioned by major yard departments and/or work may be assigned to specific shop work centers under the individual work package.

Planning, budgeting and scheduling Of work for shop work centers, ship zones and for selected trade groups are integrated completely within WORK-PAC along with cost accumulations, man-power and scheduling changes and automatic physical progress measurements.

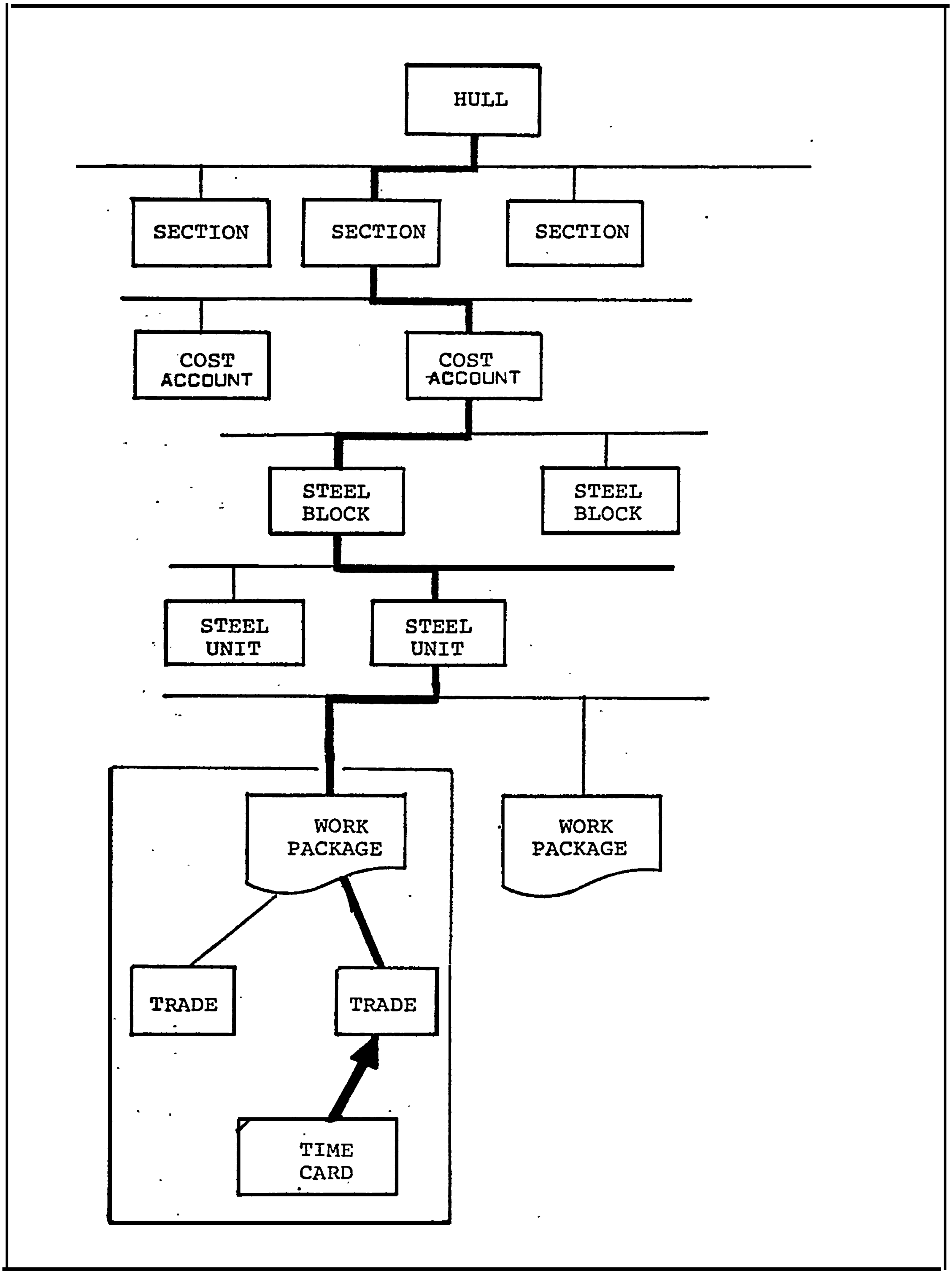
PLANNING AND BUDGETING CRITERIA

[1] WORK-PAC provides the basis For scheduling and monitoring authorized work; critical path procedures provide necessary input For developing the sequence of work and task inter-dependencies required to meet contract schedules.

[2] WORK-PAC permits the identification of physical products [ship systems, steel assemblies, ship zones, etc.], milestones [keel laying, launching, trials, etc.] and technical performance goals [manhours per ton of steel produced in fabrication, assembly, erection and on-ship welding; planned versus actual physical progress; projected final manhours versus planned targets].

[3] WORK-PAC produces time-phased schedules of labor requirements [by trade group end/or work center, if required] and utilizes current production performance data directly to provide updated changes in schedules and/or man-power requirements. Physical progress is computed for any given cost account, steel assemblv, and/or ship zone.

DISCRETE TASK WORKORDERS



CHARACTERISTICS OF A WORK PACKAGE

- ITS SIZE AND DURATION ARE LIMITED TO RELATIVELY SHORT SPANS OF TIME TO MINIMIZE THE WORK IN PROCESS EFFORT
- IT HAS A BUDGET OR ASSIGNED VALUE EXPRESSED IN TERMS OF MAN-HOURS
- IT HAS SCHEDULED START AND COMPLETION DATES WHICH ARE INTEGRATED WITH THE SHIPYARD DETAIL AND MASTER SCHEDULES
- IT REPRESENTS UNITS OF WORK AT LEVELS WHERE WORK IS PERFORMED
- IT IS CLEARLY DISTINGUISHED FROM OTHER WORK PACKAGES
- WHEN COMPLETED, IT CONTRIBUTES A MEASURABLE QUANTITY TO PHYSICAL PROGRESS

```
                                                                    DATE 28/ 3/7
HULL  1976. TYPICAL 40,000 DWT TANKER                               PAGE     1
          SECTION  2. HULL OUTFIT - GROUP 2
                         ACCT 2014. CARGO HATCH COVERS
================================================================================
  21281.  FAB OF HATCH COVERS
-------------------------------------------------------------------
                                            HRS         HRS
TRADE                                     PLANNED     TO-DATE    RE-WORK
-------------------------------------------------------------------
    2. BLACKSMITHS                             4.          0.          0.
    5. BURNERS                                11.         14.          0.
    6. CARPENTERS - SHIP                      34.          0.          0.
    7. CHIPPERS & CAULKERS                     8.          2.          0.
   11. FITTERS                                60.         72.          0.
   16. MACHINISTS                             10.         13.          0.
   24. PUNCH SHED                              1.          1.          0.
   25. RIGGERS                                 8.         16.          0.
   33. WELDERS - ELECTRIC                    174.        178.          0.
   35. PREPARATION FITTER                     11.          2.          0.
   36. SHIP FITTERS                            2.          0.          0.
UNPLANNED                                      0.
                                         -------     -------     -------
                                             321.        298.          0.
          SCHED.    ACTUAL
          ----------------
START     11/ 2/7   5/ 1/7
COMPL     18/ 2/7  16/ 3/7    LATE BY   3.8 WEEKS

WEIGHT    .000408  DISTRIBUTION FACTOR    .00000   100. PCT COMPLETED

ZONE  82 UNIT      0.
```

[4] WORK-PAC provides the means to establish labor budgets for each cost account and sub-level.

[5] WORK-PAC requires that authorized work be identified primarily by discrete, short-span work packages, complete with budgeted manhours [with or without trade breakdowns] and scheduled start and finish dates. Cost accounts and sub-levels need not be developed with work packages at the outset of the contract, but may be so developed with work packages as required.

[6] WORK-PAC automatically checks on the work budgeting to ensure that cost accounts are never over-programmed with work packages.

[7] Work packages are developed under the WBS as required. A spatial feature permits developing work packages that may be distributed across any number of cost accounts, hull assemblies and/or ship zones. WORK-PAC distributes both budgeted and accumulated costs to appropriate CWBS levels automatically.

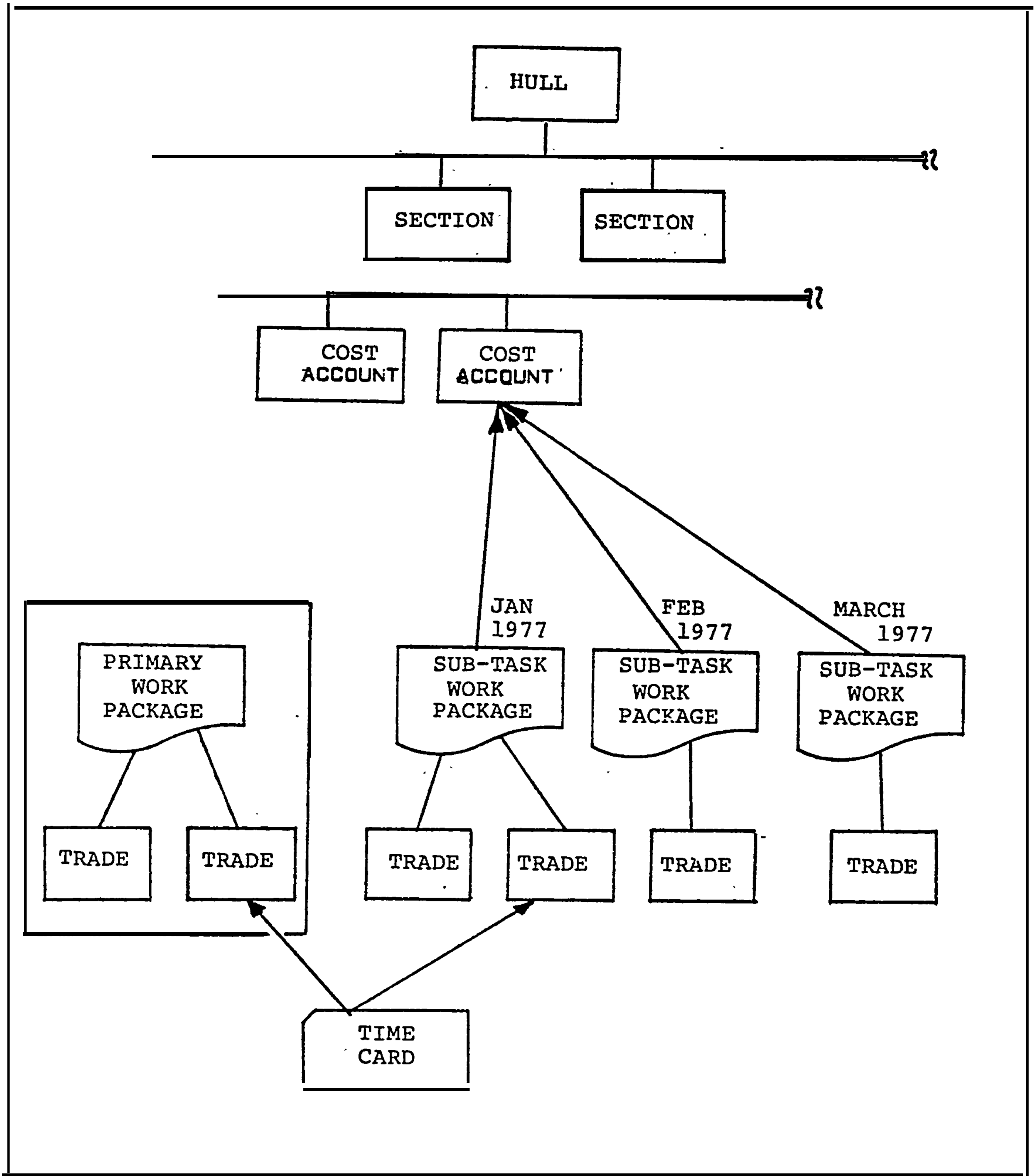
(B) WORK-PAC provides the means to define and control selected cost accounts as being specific "Levels of Effort”: activities which cannot be associated with a definable end product or result [for example, supervision, cranage, etc.] but may be controlled by time-phased budgets established for that purpose. WORK-PAC's "support” cost accounts do not project final manhour costs on the basis of performance, but merely accumulate labor charges against time-phased budgets. WORK-PAC's "factored” cost accounts generate final manhour projections either on the basis of the relative progress computed for the given account group or section or for the overall contract effort.

(9) WORK-PAC provides the means of establishing overhead budgets, either as an integral part of the WBS or as a separate yard group of cost accounts. For authorized contract work, indirect labor can be planned, budgeted, monitored, and final costs forecast directly. WORK-PAC also provides a separate accounting of re-work which may be included in the various cost status reports of the WBS , at the yard's option, at any time.

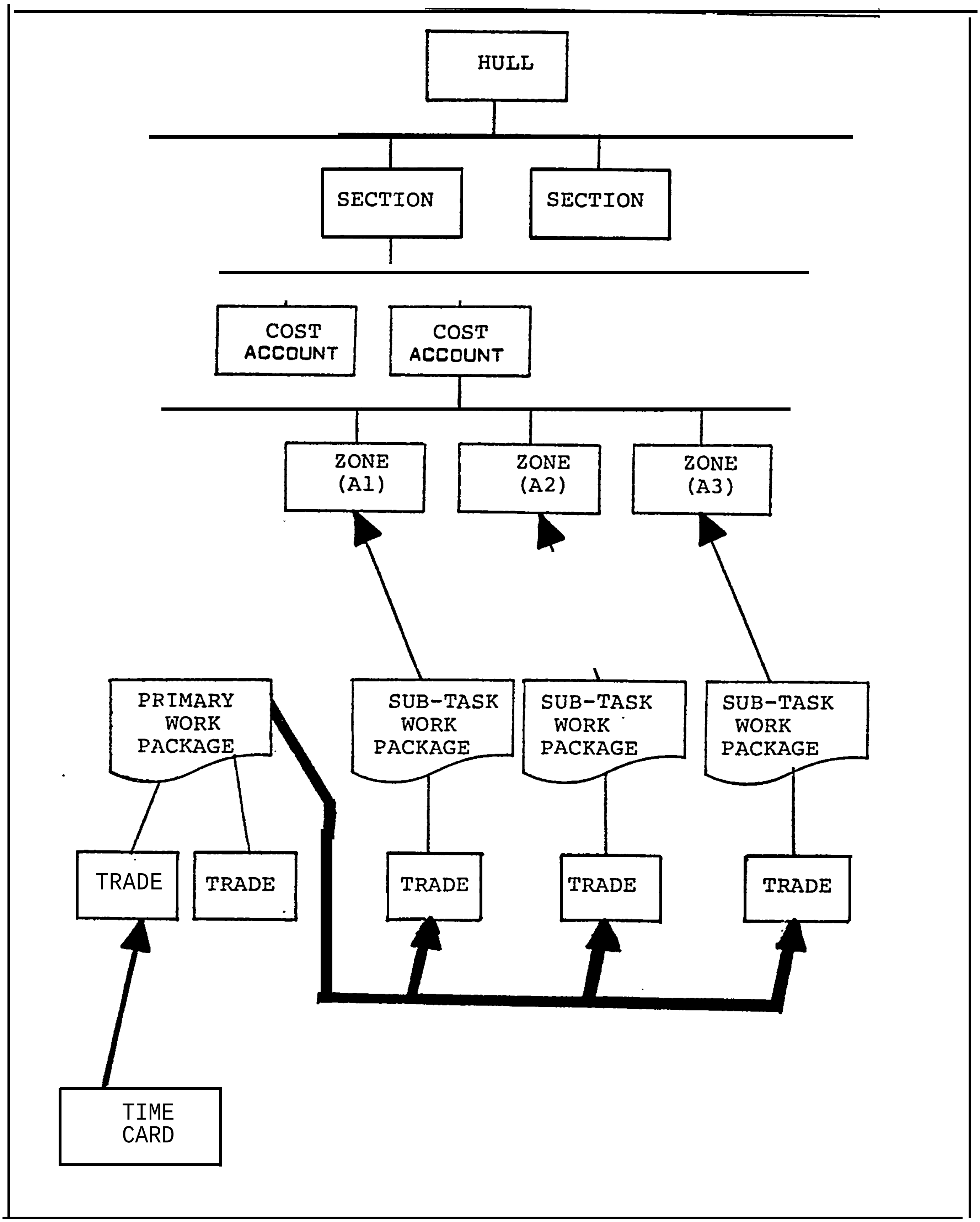
(10) WORK-PAC provides the means of identifying man hour reserves and undistributed budgets for any of the WBS cost accounts. The System is completely flexible in being able to distribute these reserves as required at any time.

[11] WORK-PAC generates contract status reports at any

TIME-PHASED WORKORDERS



DISTRIBUTED WORK ORDERS



point in time showing target costs against both accumulated and projected final cost figures and undistributed reserves. These reports may be generated for any level of the WBS. In addition, WORK-PAC computes physical progress to-date for both work packages completed and overall, including work packages still in process. These physical progress figures take into account the performance to-data For the given level.

ACCOUNTING CRITERIA

(1) WORK-PAC produces summary reports for each of the WBS cost accounts, hull assemblies and ship zones [if required]. Status reports show all accumulated manhours [with or without re-work included) against budgets and final cost projection figures. The yard may generate these reports at any time, for any period.

(2) WORK-PAC also summarizes direct costs into the yard's functional organizational elements: trade group and shop work centers. Status reports show all accumulated manhours [with or without re-work included) against budgets and final cost projections. The yard may generate these reports at any time.

(3) Basic to all WORK-PAC accounting reports are the individual work packages to which all timecards are charged. Any given package may be reported as to its schedule, budgets [including trade breakdowns, if required], actual trade charges [as planned, as chargeable to rework, and q s charged as premium manhours], and various assignments to the WBS cost accounts, hull assemblies, ship zones and shop work center.

(4) WORK-PAC provides the means to produce unit labor costs. Steel production manhours per ton (planned and projected final figures) are generated directly for fabrication, assembly, erection and on-ship welding and overall for each steel block and/or unit. Non-steel unit costs may be easily developed utilizing appropriate material and/or ship zone size parameters.

ANALYSIS CRITERIA

[1] WORK-PAC can produce accumulated and final cost projection data on any timely basis required. The System can produce such information as long as timecard entries are current. and entries of work package completions are reasonably current as well:

(a) Budgeted costs for work scheduled and for work performed

(b) Actual costs For work scheduled and For work performed

(c) Projected costs for work scheduled and For work performed

(d) Cost variances in terms of labor manhours as exhibited to-date and estimated at completion

(e) Schedule variances in terms of both labor manhours and calendar weeks

[2] WORK-PAC provides the flexibility to produce at any point in time both labor cost and schedule detail to any required degree: from overall contract to individual WBS cost accounts and sub-levels,to specific work packages, trade groups and shop work centers. Both work performance data and schedule slippage information can be obtained directly for the work effort requiring management attention and remedial response.

(3) WORK-PAC summarizes data elements and associated cost/schedule variances through the yard’s organizational structure as required.

(4) WORK-PAC produces convenient visual indicators of work slippages, cost over-runs, and excessive man-power requirements. Special raports may be generated to provide detail information about problem areas. WORK-PAC's "STATUS HISTORY" report provides an historical trend analysis of production's performance and of management's success to remedy problem areas.

[5] Because WORK-PAC provides an expedient means to pin-point both reel and potential problem areas and to generate only the degree of detail required for management review, procedures for locating and resolving these problems become systematic and opportunities for resolving them much improved with the more immediate and complete selection of

facts and analyses available from WORK-PAC.

REVISIONS AND ACCESS TO DATA CRITERIA

[1] WORK-PAC enables contractual changes to be installed with very little effort; their affects on budgets and schedules and man-power requirements can be reviewed immediately.

[2] Effects of contractual changes can be reviewed easily at all levels Of the WBS, down to the individual work packagas required to expedite the added effort.

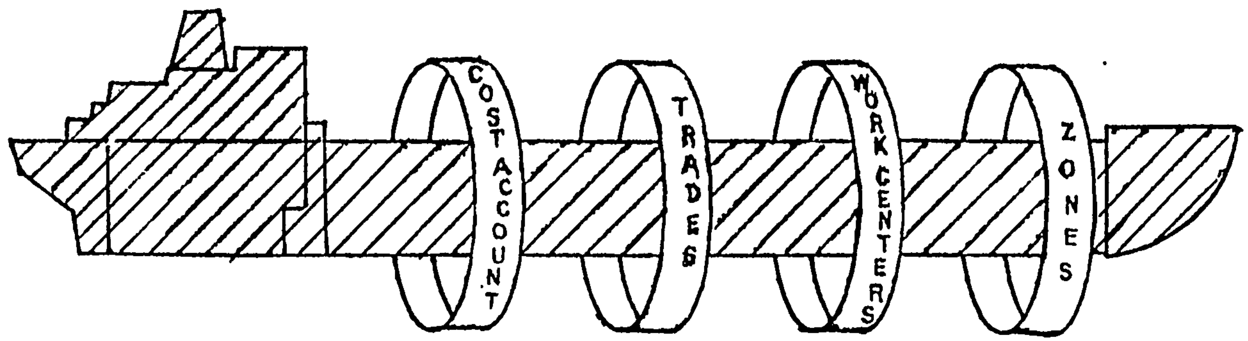
[3] WORK-PAC does not permit retroactive changes to records pertaining to work performed, except for corrections to errors and routine accounting adjustments.

[4] WORK-PAC prevents revisions to the contract baseline except as required for contractual changes resulting in formal re-programming.

(5) WORK-PAC reports provide the documentation necessary of changes to the performance measure. ment baseline at any point in time.

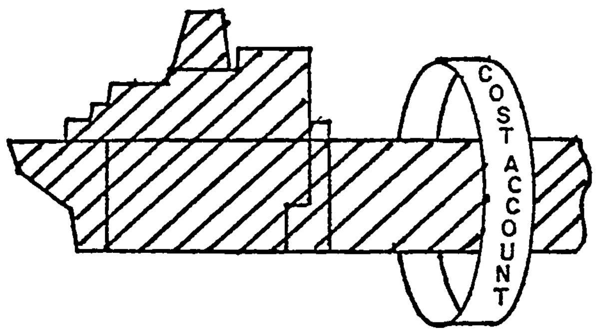
[6] WORK-PAC utilizes a number of security procedures and System Access Keys to restrict unauthorized use and access of the yard Database information.

FOUR DIMENSIONS OF CONTROLS:



- COST COUNTS
- TRADE
- WORK CENTERS
- ZONES

FIRST DIMENSION:



COST ACCOUNTS (WBS)

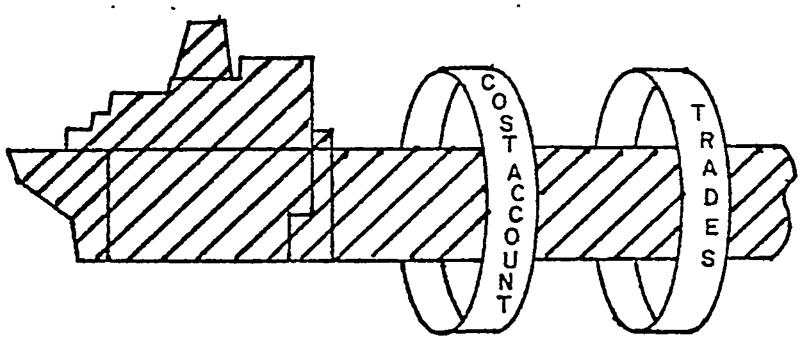
COMPLETE ANALYSIS OF EACH COST ACCOUNT SHOWING:

- BUDGETS
- CUMULATIVE HOURS SPENT
- PROJECTED FINAL COST
- PHYSICAL PROGRESS
- SCHEDULE DELAYS IN TERMS OF MANHOURS AND WEEKS
- PERIOD REPORT SHOWING:
  - HOURS SPENT SINCE LAST REPORT
  - PROJECTION CHANGE SINCE LAST REPORT
  - CHANGE IN SCHEDULE SINCE LAST REPORT
- **STATISTICAL TREND ANALYSIS OF FOUR MOST RECENT REPORT PERIODS**

FOR STEEL COST ACCOUNTS:

- MANHOURS PER TON DATA FOR EACH STEEL BLOCK AND UNIT
- PHYSICAL PROGRESS FOR EACH STEEL BLOCK AND UNIT
- BOTH REAL AND EQUIVALENT STEEL TONNAGE PRODUCTION FIGURES FOR EACH STEEL COST ACCOUNT OVERALL AND FOR EACH OF THE LAST FOUR REPORT PERIODS
- STEEL BLOCK ESTIMATING FACTORS

SECOND DIMENSION:



TRADES

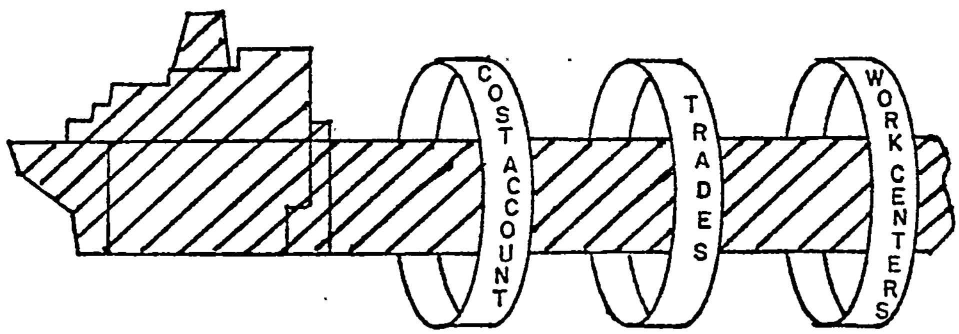
TRADES ARE THE PRIMARY RESOURCE REQUIRED TO BUILD A SHIP

TRADES MAY-TRANSCEND SHIP SYSTEMS, ZONES AND WORK CENTERS.

REPORTS ARE GENERATED SHOWING:

- TRADE PROGRESS BY ZONE
- TRADE PROGRESS BY WORK CENTER
- TRADE PROGRESS BY COST ACCOUNT

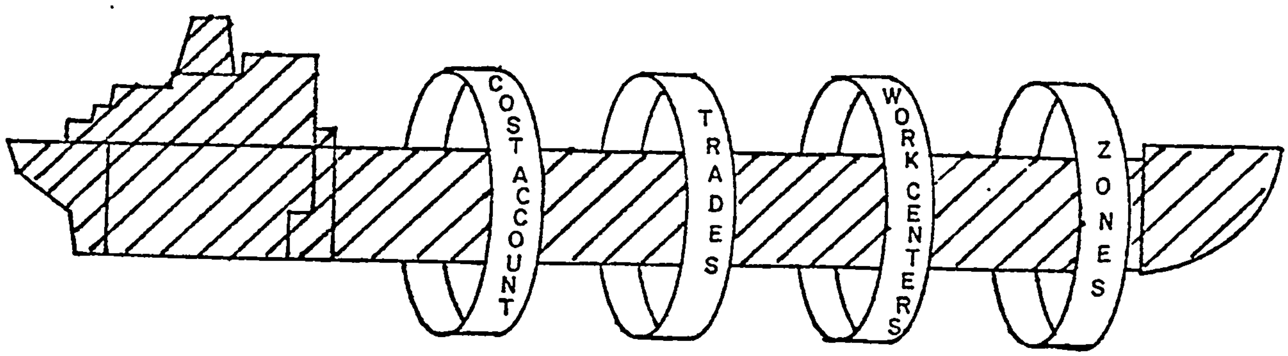
THIRD DIMENSION:



WORK CENTERS

- WORK CENTERS ARE SHIPYARD LOCATIONS ASSIGNED TO FABRICATE, ASSEMBLE, INSTALL, TEST OR DESIGN EACH COMPONENT OF EACH SHIP SYSTEM
- ANALYSIS OF BUDGETS VS ACTUAL COST AND PHYSICAL PROGRESS FOR EACH WORK CENTER'S BUDGET, AS IT RELATES TO THE TOTAL COST ACCOUNT BUDGET
- WORK CENTER CONTROL ALLOWS THE SCHEDULING OF WORK CENTER MANPOWER AND MATERIAL RESOURCES TO MEET (AND INTEGRATE) OVERALL SHIP SCHEDULES

FOURTH DIMENSION:

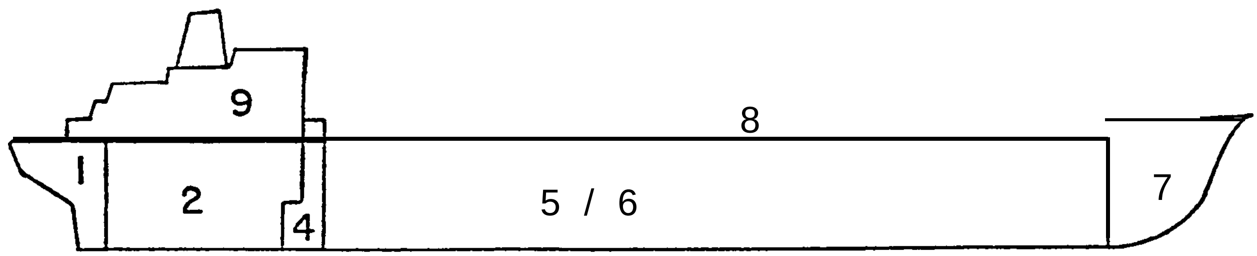


ZONES

ZONES ARE PHYSICAL AREAS WITHIN A SHIP THROUGH WHICH ONE OR MORE ENGINEERING SYSTEMS PASS.

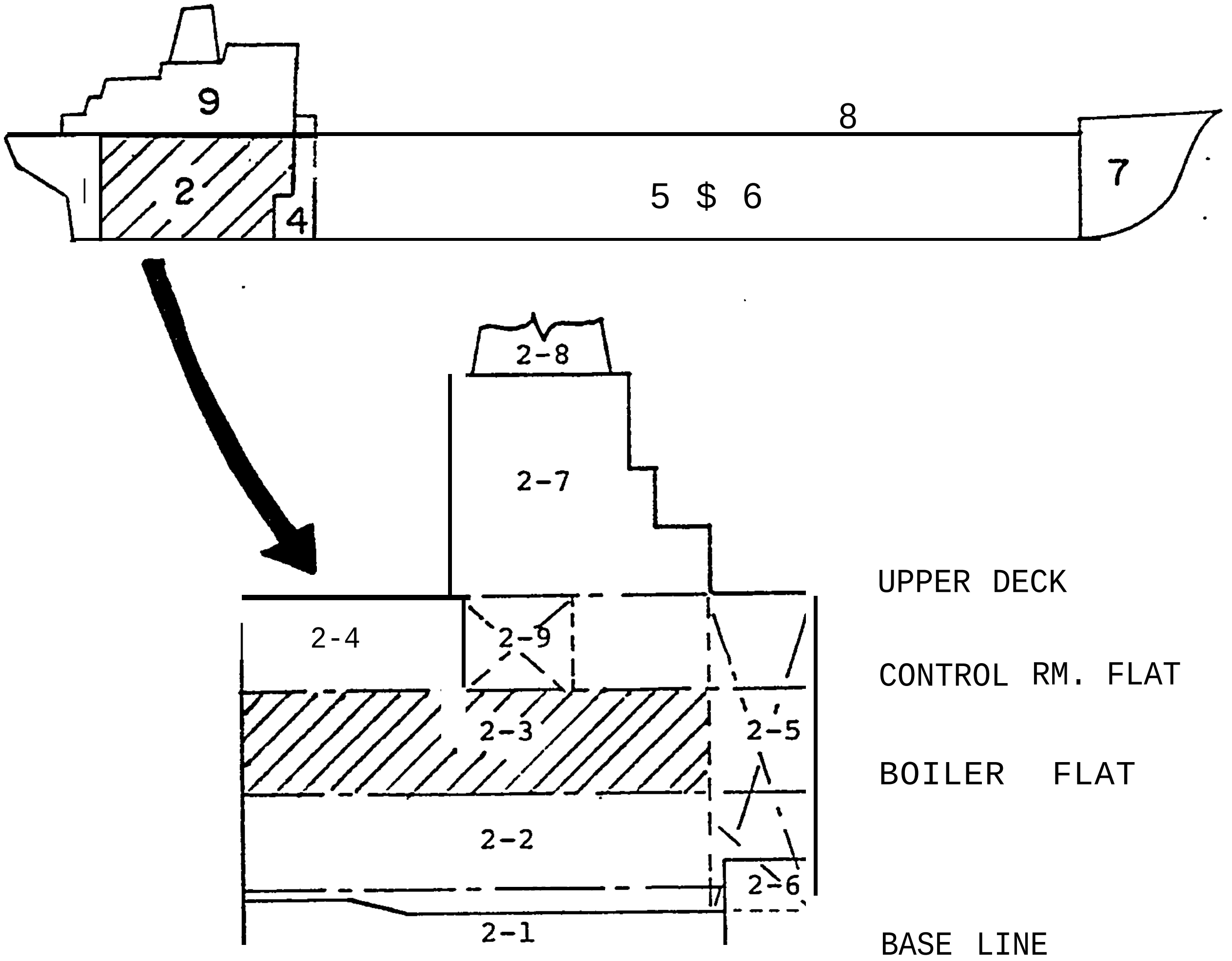
ZONE CONTROL ASSISTS IN THE PROPER SCHEDULING OF MEN AND MATERIAL. MORE IMPORTANTLY, ZONES INCREASE CONTROL OF LABOR BY MAXIMIZING VISIBILITY OF HOURS EXPENDED ON THE SHIP, AND THE EFFECT OF THESE HOURS TOWARDS PHYSICAL PROGRESS.

ZONE CONCEPT



ZONE	DESCRIPTION (GEOGRAPHICAL AREA)
1	AFT PEAK AND AFT ENGINE ROOM BULKHEAD
2	ENGINE ROOM
3	SPARE
4	APT PUMPROOM (FOR STEEL WORK THE PUMP-ROOM IS INCLUDED IN THE CARGO TANK AREA)
5	CARGO AREA; CENTER TANKS
6	CARGO AREA; WING TANKS
7	FORE BODY
8	WEATHER DECKS
9	SUPERSTRUCTURE

ZONE CONCEPT (con't)



SUB ZONE	GEOGRAPHICAL AREA
2-1	ENGINE ROOM UNDER FLOOR PLATE LEVEL
2-2	ENGINE ROOM ABOVE FLOOR PLATE TO BOILER FLAT
2-3	ENGINE ROOM BOILER FLAT TO CONTROL ROOM FLAT
2-4	ENGINE ROOM CONTROL ROOM FLAT TO UPPER DECK
2-5	HEAVY FUEL OIL TANK
2-6	HEAVY FUEL OIL SETTLING TANK
2-7	ENGINE ROOM CASING
2-8	ENGINE ROOM FUNNEL
2-9	MAIN CONTROL ROOM

PROGRESS & FINAL COST PROJECTIONS

WORK-PAC automatically measures physical progress in a number of different areas:

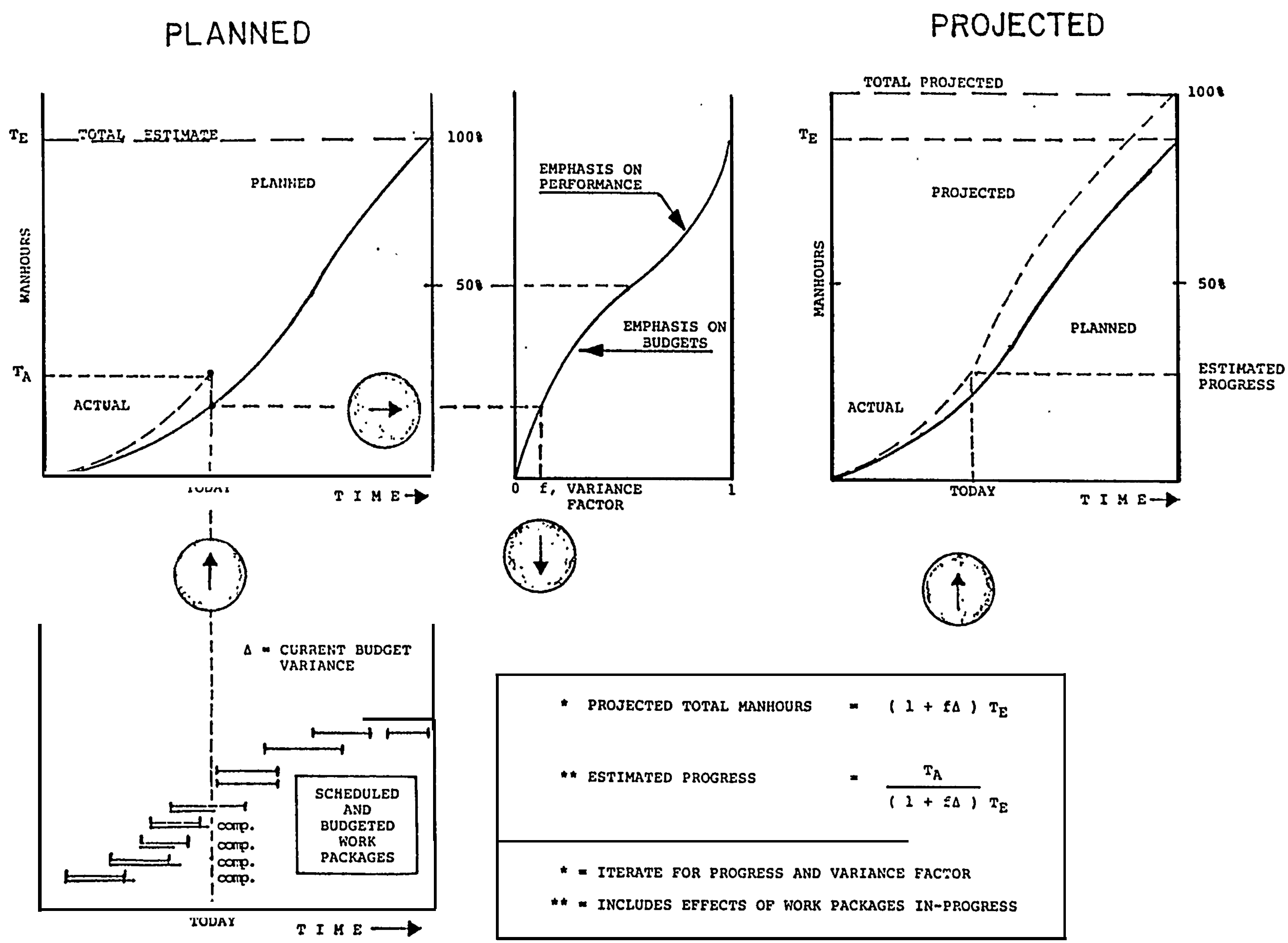
1. by project total
2. by cost account section
3. by individual cost account
4. by steel assembly
5. by ship zone
6. by shop work centar
7. by trade group

WORK-PAC utilizes information of what work packages have been completed [closed out] and extrapolates for the progress of work uncompleted, but under way.

The automation of the progress measurements allows cost controllers to apply more of their efforts to resolving specific yard production problems. The laborious task of collecting and developing progress information for management review is done entirely by the system.

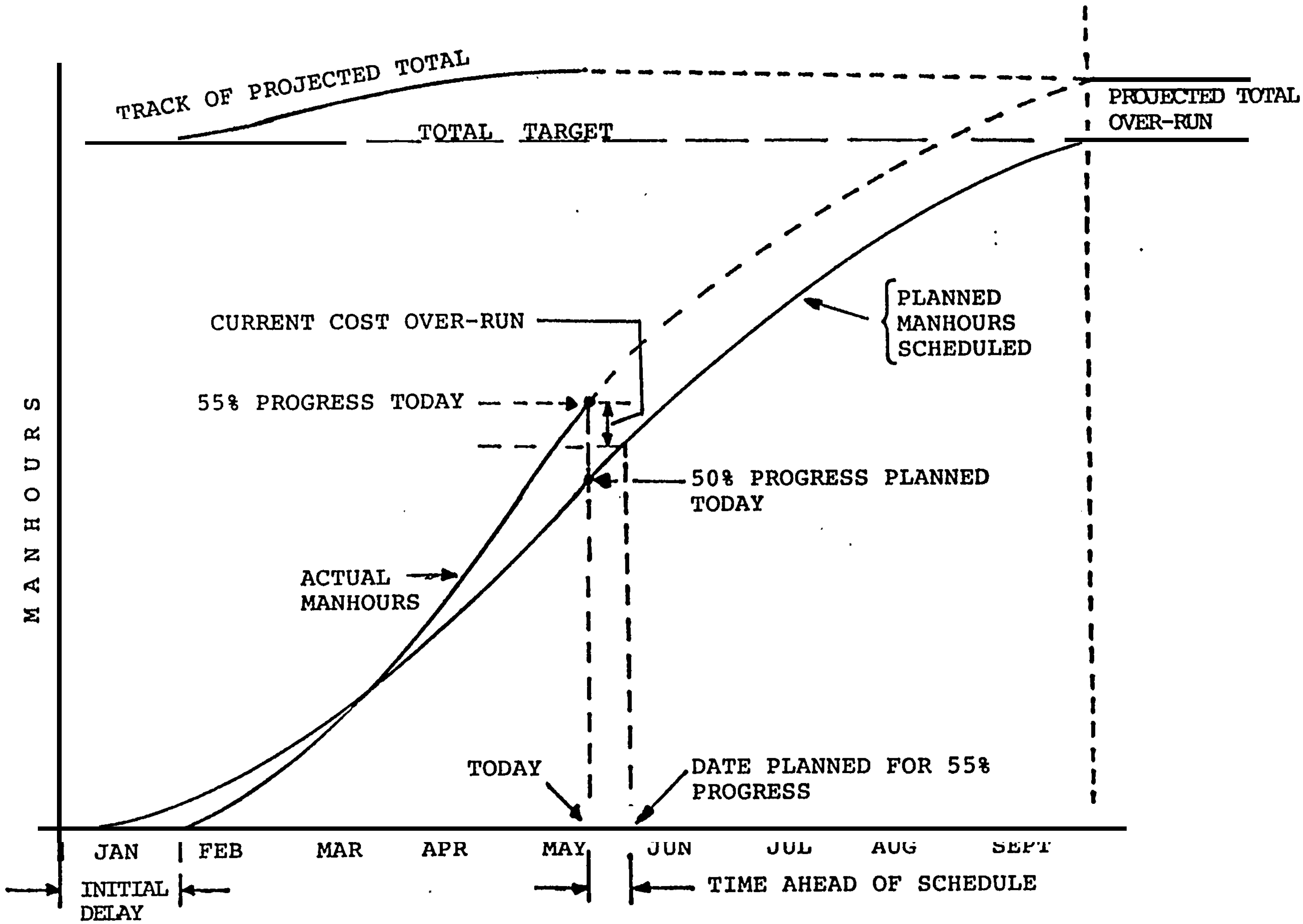
Through sophistocated statistical analysis procedures, WORK-PAC generatas highly accurate final manhour cost projections in the same areas of interest outlined above.

WORK-PAC utilizes relative work performance of completed work packages, and depending upon the relative progress exhibited by the overall effort, applies this information to develop final cost estimates. These cost projections are the more obvious means to determine if the job is being executed as planned. WORK-PAC'S development of progress also permits automatic determination of whether overall schedules as planned area being met as well. An early opportunity to Predict over-runs and/or schedule slippages offers an early opportunity to effect appropriate changes to eliminate or at least minimize problems before they become critical.



AUTOMATIC TRANSITION FROM PLANNED TO PROJECTED COST SIMULATION

WORK-PAC COST/SCHEDULE VARIANCE ANALYSIS



SHIPYARD REQUIREMENTS

WORK-PAC has been designed to be integrated within a given shipyard quickly and easily with very little disturbance to existing operations and procedures. In fact, WORK-PAC utilizes most existing procedures and cost account breakdown categories; WORK-PAC is a product of a real-life shipyard environment.

Since WORK-PAC requires the adoption of the work package concept as the Fundamental means for authorizing and controlling production efforts, the yard must provide charging to a work package number. Work packages must be developed for all shipyard activities and the WORK-PAC PROCEDURES MANUAL provides guidance in this effort. The planning tack must, of course, be work package oriented and this basic approach has proved to offer significant advantages in estimating and scheduling manpower requirements.

WORK-PAC will mean a transfer of effort from manual data collection and physical progress measuring to more intense planning and scheduling using WORK-PAC for both budget development and job simulations. The obvious benefits from this added emphasis on planning has proved to be earlier scheduling, reduced overhead and improved work/material coordination.

SOFTWARE SPECIFICATIONS

PROGRAM DESIGN

The Sytem is written entirely in standard ANS FORTRAN IV and is operational an the following computers:

IBM 360/85 [128K bytes]

IBM 370/155 [128K bytes]

IBM 370/165 [128K bytes]

UNIVAC ll08/Executive 8 (32K words)

UNIVAC 90/30 (128K bytes)

The above listing includes core requirements of the System with overlaying of System Function Modules.

The software has been designed in accordance with the so-called "Structured programming" concept. All functions have been written as seperate routine modules, each of which utilizes a common library of System utility routines for file accessing, sorting, merging, etc. Future functions may be added quite simply.

Since the System has been written to the ANS standard, the program is essentially machine independent for those operating systems featuring the standard compilors.

The System does employ direct access file techniques, but only through one FORTRAN subroutine, which alone is tailor-made for the given operating system. Several versions of this routine are available, including one featuring a rotating buffer scheme that can reduce the number of record accesses significantly.

DATABASE

The Database has been constructed of fixed record length files for the activity levels and for the workorders; a third file of similar characteristics exists for the various trade catagories. These files are accessed randomly and may be defined in whatever manner suits the user.

The size of the Database is directly dependent upon the size and number of projects to be maintained. A typical project requiring one million manhours should average about 500 manhours per work order; with all activity levels, including steel assemblies and zones, the Database would require approximately 400K words or 1.6K bytes.

A fourth file maintains Database file parameter information and totals only 60 words or 120 bytes.

The System uses scratch files, which should be prescribed as about twice the size of the Database; they we used for various utility purposes such as merging, sorting, and analysis processing.

SYSTEM SECURITY

Considerable effort has been expended to develop routine procedures for making back-up copies of the Database at regular intervals. In the commercial timesharing version, three different methods of back-up are provided: by the timesharing vendor's normal daily back-up; by the yard's own daily back-up; and by a card-image copy-out and load function built into the System program.

The System has been designed with a pass key entry card which permits only authorized execution of the System functions. This pass key may be changed at any time by the department in control of the System.

The Database files are normally read/write protected to prevent inadvertant accessing by other users; they are also given special assignments such that a given run has exclusive use of these files at any given time.

ERROR HANDLING

The Systmm employs numerous data checks and generates appropriate diagnostic messages to minimize potential errors and/or inconsistencies of input information. The System also generates special flags and warnings whenever specific projects exhibit questionable work performance characteristics.

DOCUMENTATION

The System is complete with a User's Manual. which provides detail instructions for operating each of the System's function modules and numerous examples; a Programmer's Manual, which provides software and Database characteristics; a Procedure's Manual giving in-depth discussions of the shipyard's organizational requirements and recommended practices for maximizing the benefits to be gained by the System.

SYSTEM INTERFACES

WORK-PAC has been designed to be readily expandable into other application areas, including direct link-ups with other application programs [For example, detailed material handling and inventory control, critical path scheduling, basic ship estimating, and employee payroll].

WORK-PAC is a collection of application modules under the control of a primary System executive, which selects appropriate function modules as specified by the given user. Extending existing modules and/or adding new ones is completely compatible under the WORK-PAC software design.

CURRENT LIMITATIONS

WORK-PAC presently has the following self-imposed limitations:

Number of projects: 99,999
Number of cost accounts per project: 9,999
Number of steel blocks: 1369 alfa.numeric par project
Number of ship zones: 1369 alfa-numeric per project
Number of steel units: 9999 per project
Number Of work packages: 999,999 per work center per project
Number of work centers: 99
Number of trade groups: 99
Number of timecards: unlimited per day

HARDWARE REQUIREMENTS

WORK-PAC currently requires the following hardware equipment:

a) 36K words (128K bytes) central processing core, excluding the mainframe operating system

b] Direct access magnetic disk devices

2.5 M words [1OM bytes] Database *
2.5 M words [1OM bytes] temporary Files*

c] 80-column card reader or key-to-tape or key-to-disk device

d] 128-character line printer

e] one magnetic tape device for Database back-up

f] FORTRAN IV compiler supplied with the mainframe operating system

g] Random access routines callable from FORTRAN supplied with the mainframe operating system

h] Program overlaying capabilities

Should WORK-PAC be operated remotely, the terminal equipment must have suitable communications gear [hardware and terminal software] to be intelligible to the central computer. Considerations must be given for terminal communications either by direct line, dial-up, WATTS or DATA ROUTE.

* File storage requirements are based upon work orders for approximately 7 million manhours.

COMPUTER PROCESSING COSTS

The actual computer processing costs can vary considerably, depending upon a number of Factors:

1. number of yard projects being processed at any given time period
2. extent and datail of the work breakdown categories; number of work orders issued
3. number of timecards processed daily
4. extent of planning changes entered into WORK-PAC
5. extent of corrections required For incorrect timecard chargings
6. number and type of reports required
7. pricing algorithms employed by the given computer facility used
8. extent by which non-prime time computer processing can be utilized
9. extent by which local telephone Service (if remote time-sharing) can be used
10. extent by which volume discounts Can be applied by using the given computer for other than WORK-PAC processing

A typical time-sharing cost [1977] for a new ship construction is estimated to be about $2000 per month per 100,000 yard manhours per month. This cost includes an averaged cost of installing cost accounts, steel assemblies, zones and work packages; proceeding timecards,; and producing various management reports, etc. This cost does not include any charges for terminal hardware nor amortized costs for the WORK-PAC software and training.

U.S.DEPARTMENT OF DEFENSE 7000.2 REPORTING

WORK-PAC satisfies the Cost/Schedule Control Criteria of the Department of Defense 7000.2 instruction by providing an integrated and systematic analysis of labor performance in a highly disciplined environment. WORK-PAC not only furnishes information but more importantly gives management alternative solutions to potential problems.

The effectiveness of WORK-PAC is demonstrated in the following check list which highlights the criteria requirements of 7000.2:

- Defines all authorized work and related sources to meat the contractual requirements, using WBS frame-work.

- Identifies work centers responsible for work accom-plishment and assigns budgets.

- Provides for the integration of the following Functions:

  Planning

  Scheduling

  Budgeting

  Work Authorization

  Cost Accumulation

- Identifies the managerial positions responsible for controlling overhead [indirect costs].

- Provides for integration OF the WBS with the ship-yard's functional organization permitting cost/ schedule performance measurement between the WBS and work centers [functional organization).

- Schedules the authorized work in a manner describing the sequence of work and identifies the significant task relationships required to meet the contract.

- Identifies physical products, milestones, technical performance goals and other indications used to measure output.

- Establishes and maintains a time-phased budget base. line at the cost account level against which contract performance can be measured.

- Describes completely the mathematical method for measuring physical progress.

- Establishes budgets for all authorized work with separate identification of cost elements.

- Establishes budgets using hours as the measurable unit For discrete, short-span work packages.

- Shows that the sum of all work package budgets, within a given cost account, equals the cost account budget.

- Identifies and controls level of effort activities by time-phased budgets established For this purpose.

- Establishes overhead budgets for the total costs of-each significant organizational component whose expenses will become indirect costs.

- Identifies management reserves and undistributed budgets.

- Shows contract target costs plus estimated costs of authorized, but unpriced work, as reconciled with the sum of all internal contract budgets and management reserves.

- Records direct costs on an applied basic consistent with budgets in a system that is formally controlled.

- Shows that within the cost account, direct labor charges were made at the same time direct resources are actually consumed.

- Summarizes direct costs from cost accounts into the WBS without allocation of a single cost account to two or more WBS elements.

- Summarizes direct costs from the cost accounts into the work centers [functional organization].

- Records all indirect costs which will be allocated to the contract.

- Identifies the bases for allocating the cost of apportioned effort.

. Identifies at the cost account level, on a monthly

    Budgeted Cost for Work Scheduled [BCWS)

    Budegted Cost for Work Performed (BCWP]

    Budgeted Cost for Work Performed versus Actual Cost for the Same Work

    Variances resulting from the above comparisons

- Identifies on a monthly basis, in detail, budgeted indirect costs, actual indirect costs and variances.
- Summarizes the data elements and associated variances listed above through the shipyard's organization and the WBS to the specified reporting level.

- Demonstrates that a contractual change is incorporated in a timely manner, end the effects of such changes to existing budgets and schedules.
- Prohibits retroactive changes to records pertaining to work performed that will change previously reported amounts for direct costs, indirect costs or budgets, except for the correction of errors.
- Prevents revisions to the contract budget baseline except for those which are government directed.
- Demonstrates that changes to the performance measurement baselines are internally documented and that timely notification of these changes are provided.
- Demonstrates the amount and level of detail the contracting officer may have access to in determining the status and progress of the project.

THE INGALLS PRODUCTION PLANNING AND CONTROL SYSTEM

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Mr. Davidson is Manager of the Business Applications group at Ingalls Shipbuilding. He is responsible for the planning, design, development, programming, implementation and administration of all non-technical data processing methods and systems to support the production and management effort at Ingalls.

In the past, he has worked for Computer Sciences Corporation, Boeing, and divisions of Litton Industries. Dr. Davidson was also a partner in a small software firm which designed and marketed software for minicomputer applications.

INGALLS PRODUCTION PLANNING AND CONTROL SYSTEM OUTLINE

I. SYSTEM OVERVIEW

A. DEFINITION OF TERMS
B. MODULE FUNCTIONS
C. MODULE INTERFACES

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B. DESCRIPTION
C. DATA BASE STRUCTURE
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B. DESCRIPTION
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B. DESCRIPTION
C. INTERFACES

V. LABOR MANNING MODULE

A. FUNCTION
B. DESCRIPTION
C. INTERFACES

VI. LABOR RESCHEULING MODULE

A. FUNCTION
B. DESCRIPTION
C. INTERFACES

VII. LABOR REPORTING MODULES

A. PLANNING AND SCHEDULING
B. CONTRACT PERFORMANCE
C. BUDGET PERFORMANCE
D. REAL-TIME

I. SYSTEM OVERVIEW

Ingalls' Production Planning and Control System assists in planning, scheduling, budgeting and tracking each work authorization developed to support the construction of each ship. The system is comprised of modules that have specific functions within the System and some of the modules interface with other modules. To assist in understanding the Ingalls' Production Planning and Control System, a definition of terms to be used, a brief description of each module's function, and a diagram of the module interfaces follow:

A. DEFINITION OF TERMS

For purposes of this presentation, the following definitions are offered:

USER- one who inputs data to or receives data from the System.

HULL- ship.

WORK AUTHORIZATION - a logical package of related work for one part of a ship.

WORK STATION- a geographical area within the shipyard.

COST CENTER- a budget and cost collection center.

OPERATION - a craft or type of work.

CRAFT - a particular trade, such as Welder, Shipfitter, Carpenter, etc.

STANDARD BUDGET - engineered number of hours required to perform a particular type of work under ideal conditions.

COMPANY OPERATING BUDGET - standard. budget factored by performance.

CONTRACT BUDGET - baseline established based on negotiated contract values.

B. MODULE FUNCTIONS

Each module in Ingalls' Production Planning and Control System has a specific function. The basic function of each module is as follows:

1. Consolidated Data base (CDB) Module

   This module is the nucleus of the system and its function is to maintain the schedules, budgets and actusls for all work authorizations used by the Company.

2. Budget Allocation Module

   The function of this module is to programmatically distribute a Company Operating Budget and a Contract Budget to each work authorization contained in the CDB Module.

3 Labor Progressing Module

   The primary function of this module is to programmatically compute labor progress to budget for each work authorization in the CDB Module.

4. Labor Manning Module

   This modules fuuction is to programatically time-phase work authorization budgets over work authorization schedules to reflect the time-phased labor manning required to construct each ship.

5. Labor Rescheduling Module

   This module contains high-level PERT network activities of each ship and a cross-reference to all work authorizations

for each network activity. This module is used to reschedule work authorizations in the CDB Module whenever the schedule for a network activity Changes.

6. Labor Reporting Modules

There are four distinct reporting modules within the Production Planning and Control System:

a. The Planning and Scheduling module reports progress to schedule for work authorizations and statistics reflecting current schedule trends and problem areas.

b. The Contract Performance module provides schedule and budget variance reports as required by DOD 7000.2 Specifications.

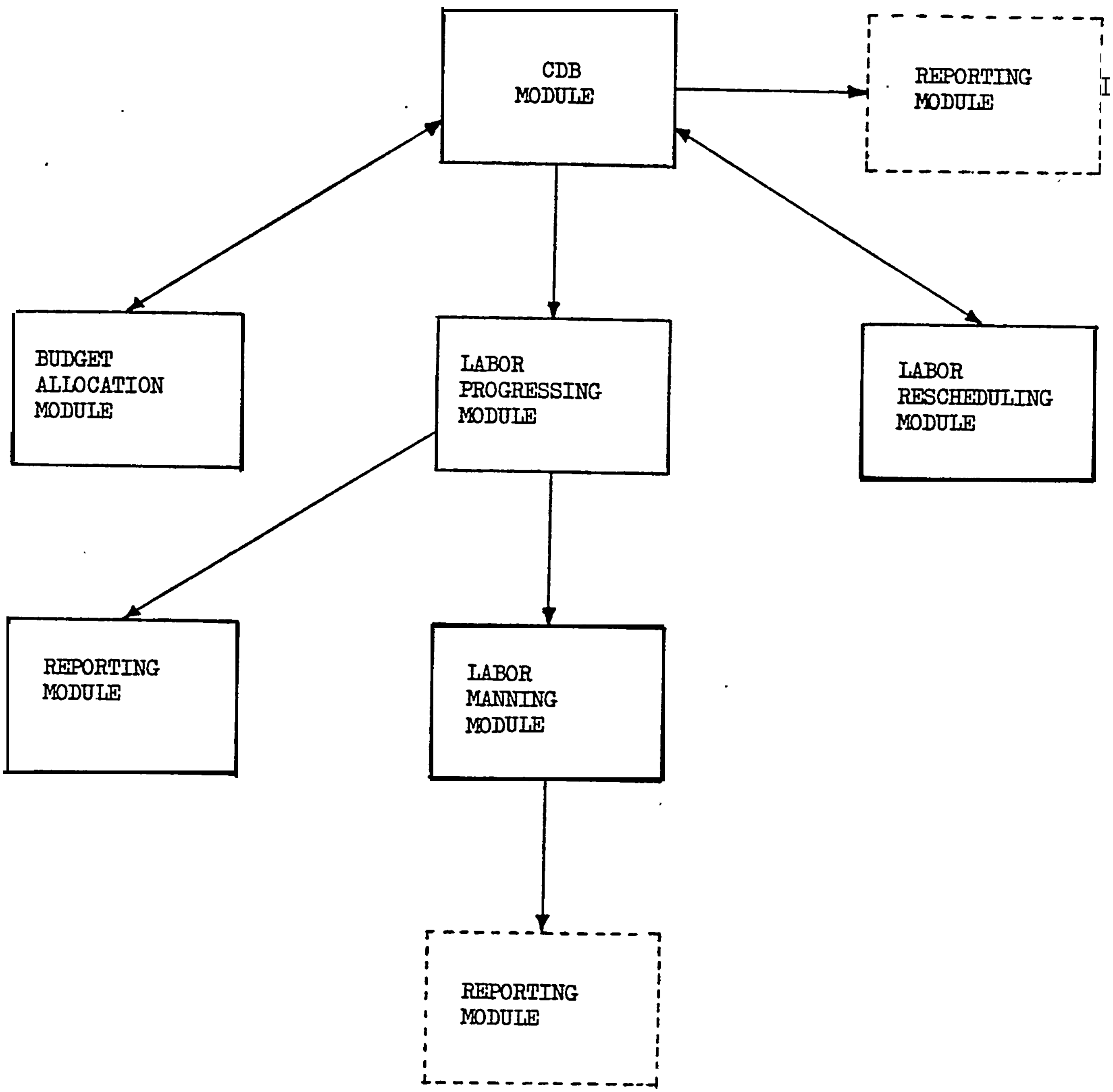
c. The Budet Performance module reports progress to budgets for work authorizations reflecting budget overruns and underruns.

d. The Real Time module provides on-line retrieval of scheduling, budgeting, and actual data from the CDB Module via terminals.

C. MODULE INTETERFACES

A diagram of the Module Interfaces is provided to reflect the module interactivity within Ingalls' Production Planning and Control System.

C. MODULE INTERFACES



II. <u>CONSOLIDATED DATA BASE MODULE</u>

A. FUNCTION

The Consolidated Data Base (CDB) is a SYSTEM 2000 Data Base containing all work authorizations that must be performed by the crafts to construct each hull and is the nucleus for Ingalls' Production Planing snd Control System.

With the Ingalls concept of constructing ships on an assembly line basis, each work authorization is identified to the work station in which the work is to be performed.

Each work authorization on the CDB contains schedule dates to provide time frames in which work is to be accomplished and also contains manhour budgets that will be required to complete the work.

The CDB provides for validation and accumulation of actual hours expended against each work authorization.

B. DESCRIPlION

The Consolidated Data Base is updated semi-weekly with input from Planning and Scheduling, Industrial Engineering snd Finance.

Planning and Scheduling Department establishes and maintains all work authorizations on the CDB, identifying each to the work station in which work is to be done and maintains appropriate schedule data for each work authorization on the CDB.

Industrial Engineering Department determines Which cost centers will be involved in supporting each work authorization, identifies each operation to be performed by each cost center and develops the manhour budget that should be expended to complete each operation. Industrial Engineering is responsible for establishing and maintaining all budget data on the CDB.

Finance provides data to the CDB for those tasks that are not directly *related* to the construction of a hull, but must be accomplished to support the construction work authorizations developed by Planning and Scheduling and Industrial Engineering.

File maintenance reports from the CDB update processes are provided to the user departments to assist in maintenance of the data for which they are responsible.

On a weekly basis, all actual hours expended by the crafts against each work authorization are validated against the CDB to insure proper labor charging to current scope of work and all valid actual hours are then booked to the CDB for tracking, progressing and budget variance reporting.

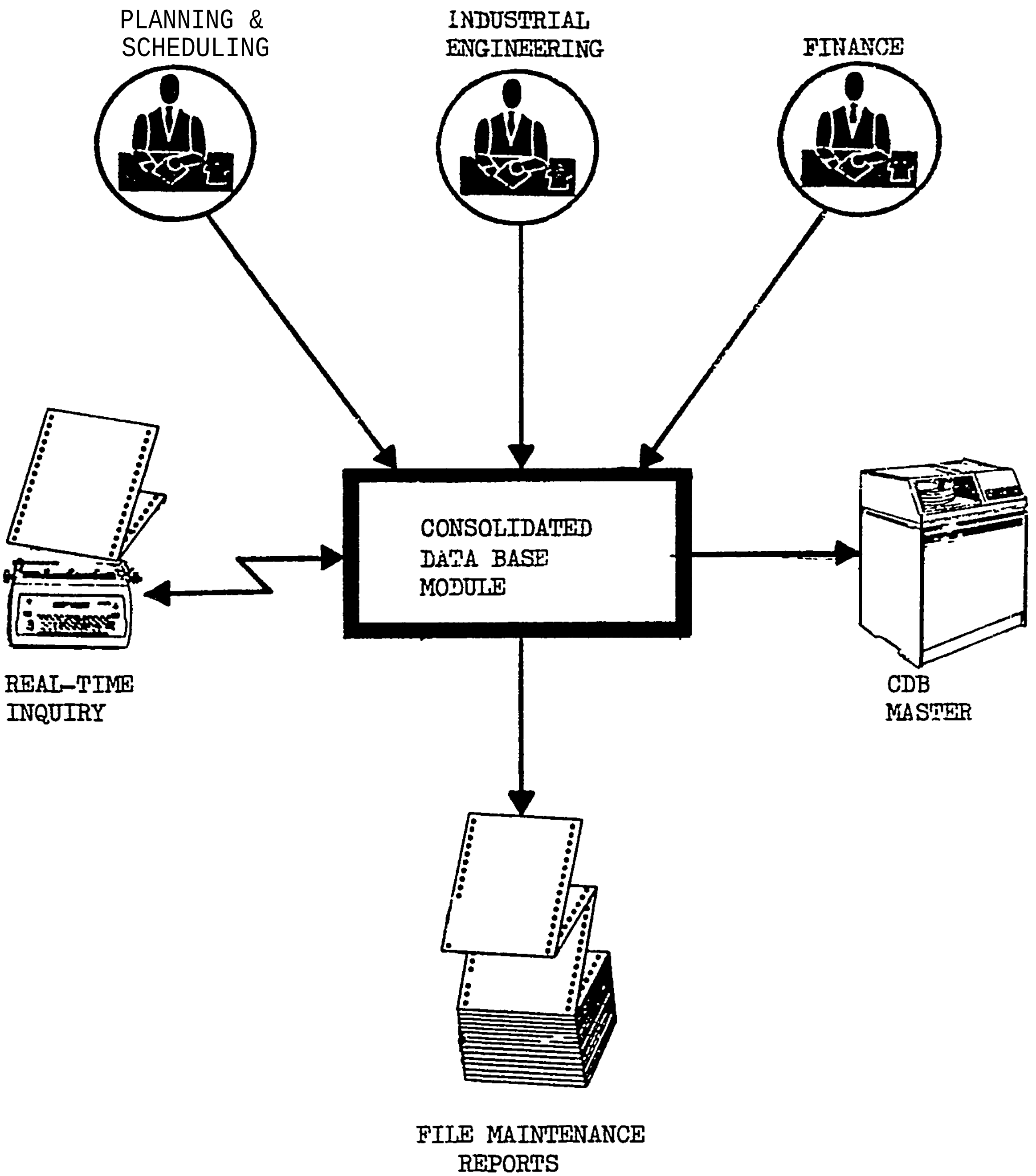
The real time inquiry capability of SYSTEM 2000 provides the user organizations immediate access to all data elements on the CDB to aid in the maintenance of this file. Inquiries also provide Craft Supervisors with immediate access to those work authorizations comprising the current scope of work so that each Supervisor can better plan and deploy available mainpower to accomplish assigned tasks.

D. INTERFACES

As the nucleus of Ingalls' Production Planning and Control System, the Consolidated Data Base provides all data that is required for the Budget Allocation, Labor Progressing, Labor Reporting and Labor Rescheduling moduales described in this presentation.

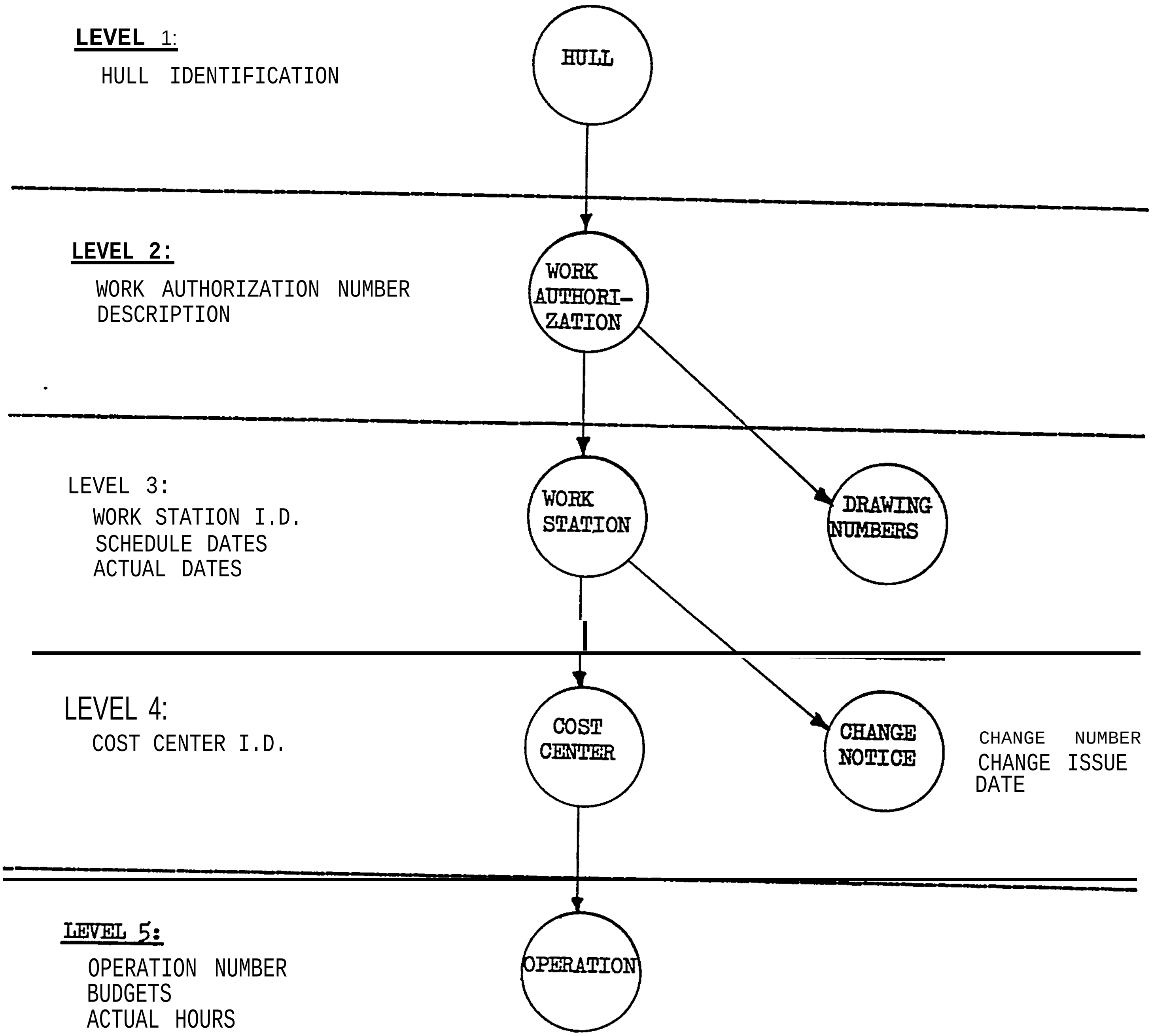
II. CONSOLIDATED DATA BASE MODULE

B. DESCRIPTION



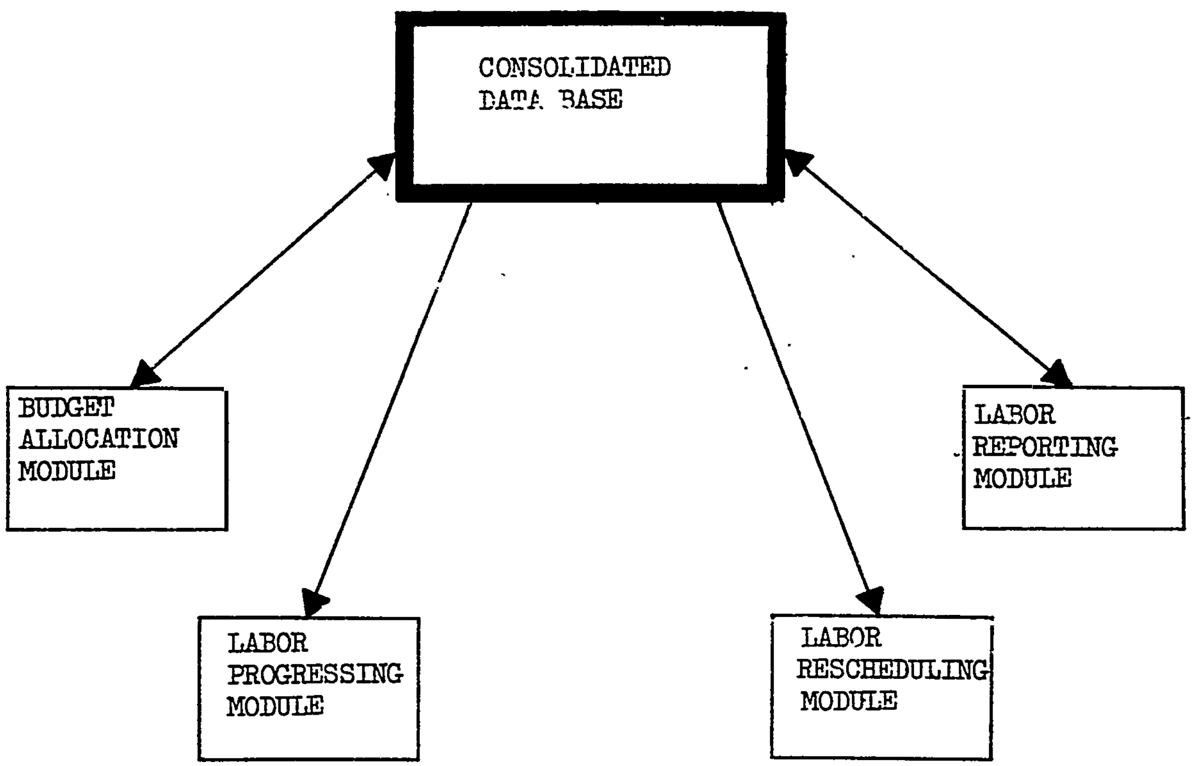
II. CONSOLIDATED DATA BASE MODULE

C. DATA BASE STRUCTURE



II. CONSOLIDATED DATA BASE MODULE

I. INTERFACES



III. BUDGET ALLOCCATION MODULE

A. FUNCTION

The Budget Allocation Module has two functions: (1) to allocate a Contract Budget to each work authorization based on the work authorizations Standard Budget, and (2) to allocate a Company Operating Budget to each work authorization based on the work authorization’s labor charges and Standard Budget.

B. DESCRIPTION

The allocation of the Contract Budget is to be performed at the beginning of a contract and reallocated only upon concurrence by the Navy. At the start of a contract, the Industrial Engineering Department inputs the Contract Budget, authorized for each cost center to construct each hull, to the Budget Allocation Module. The Budget Allocation Module then sums from the CDB Module by hull by cost center the Standard Budgets established for all work authorizations within the hull and cost center. A factor is obtained by dividing the hull, cost center Contract Budget by the hull, cost center Standard Budget. This factor is then multiplied by the Standard Budget for each work authorization for the hull, cost center yielding the work authorizations Contract Budget. Transactions with each work authorizations Contract Budget are generated by the Budget Allocation Module for updating the CDB by the CDB Module.

The allocation of the Company's Operating Budget is performed at the beginning of each fiscal year and again at mid-fiscal year. To begin an allocation process, the Industrial Engineering

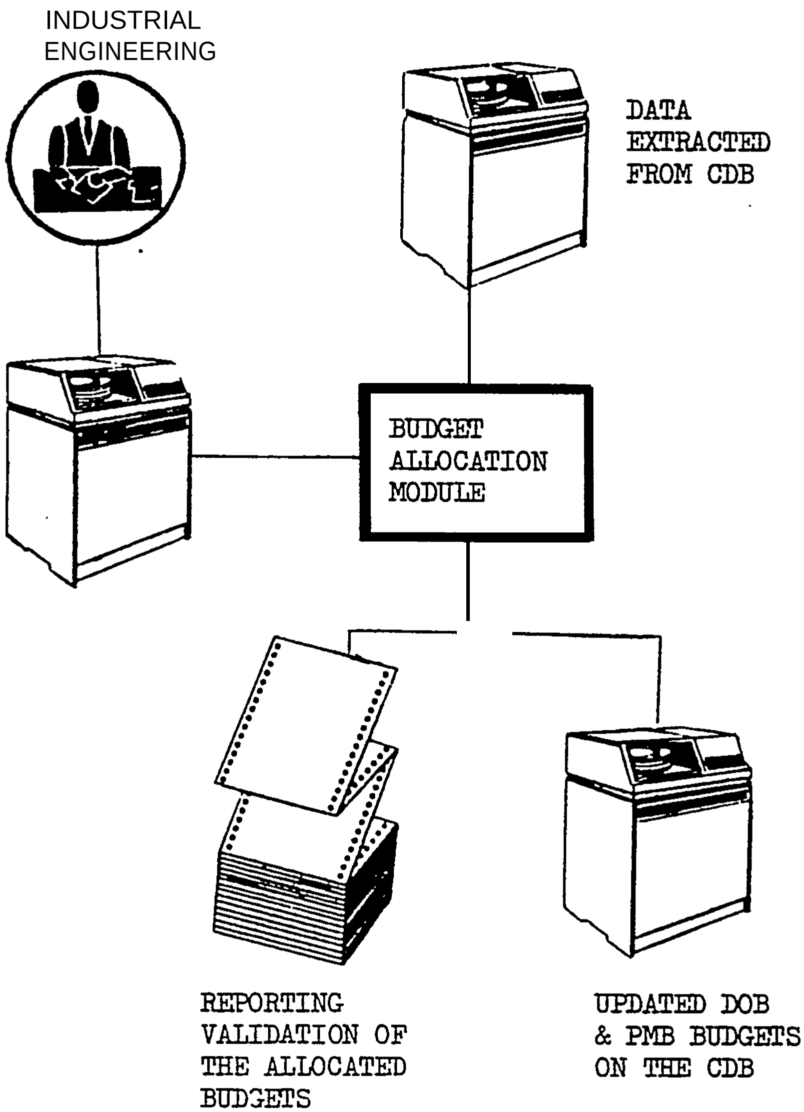
Department inputs the Company’s Operating Budget, authorized for each cost center to construct each hull, to the Budget Allocation Module. The Budget Allocation Module then distributes the budget, to each work authorization for the hull, cost center, based on the status of the work authorization. A two step process is required to accomplish the allocation: first, each completed and in-process work authorization is given an amount of budget equal to the labor charges incurred by the work authorization; second, the Operating Budget not allocated in the first step is allocated to the in-process and not-started work authorizations by the ratio of the work authorizations “to-complete” standard to the hull, cost centers “to-complete” standard times the Operating Budget not allocated in the first step. Exception reports are generated if an excess or deficient Operating Budget is input to the Budget Allocation Module by the Industrial Engineering Department. To complete the process, the Budget Allocation Module generates transactions with each work authorizations Operating Budget for updating the CDB by the CDB Module.

C. INTERFACES

The Budget Allocation Module extracts work authorizations with their Standard Budgets from the CDB Module; allocates a Contract Budget or Company Operating Budget to each work authorization; and generates transactions with each work authorization’s allocated budget back to the CDB Module for updating the CDB.

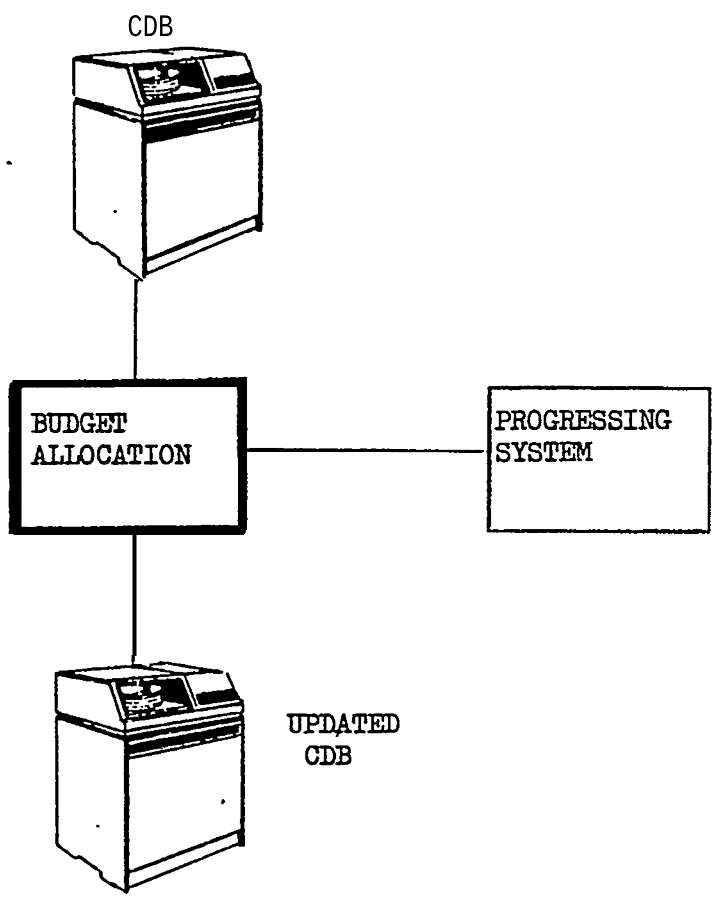
III. BUDGET ALLOCATION MODULE

B. DESCRIPTION



III . BUDGET ALLOCATION MODULE

C. INTERFACES



IV. LABOR PR0GRESSING MODULE

A. FUNCTION

The Labor Progressing Module computes budget progress for work authorizations directly associated with a hull's construction and then uses this progress to compute the supervision and support work progress associated with the direct construction progress. This module then generates various reports, reflecting budget progress and performance, to be used by shipyard management. This module has the capability of reflecting progress/performance to either the Contract Budget or the Company Operating Budget or the Standard Budget.

B. DESCRIPTION

At mid-month each month, a report of all in-process work authorizations and those scheduled to start within thirty days is generated from the CDB by the reporting module. This report is distributed to the crafts performing the work; they record their percent complete for each work authorization; and at month end, the percent completes are input to the CDB Module to be recorded on the CDB. During the first week after month end, the Progressing Module extracts all work authorizations from the CDB and computes progress in a two step process. First,for each work authorization associated with a hulls construction, the module multiplies the percent complete, established by the craft, times the budget yielding earned budget; a completed work authorization is one hundred percent complete. The earned budget and total budget for each direct construction

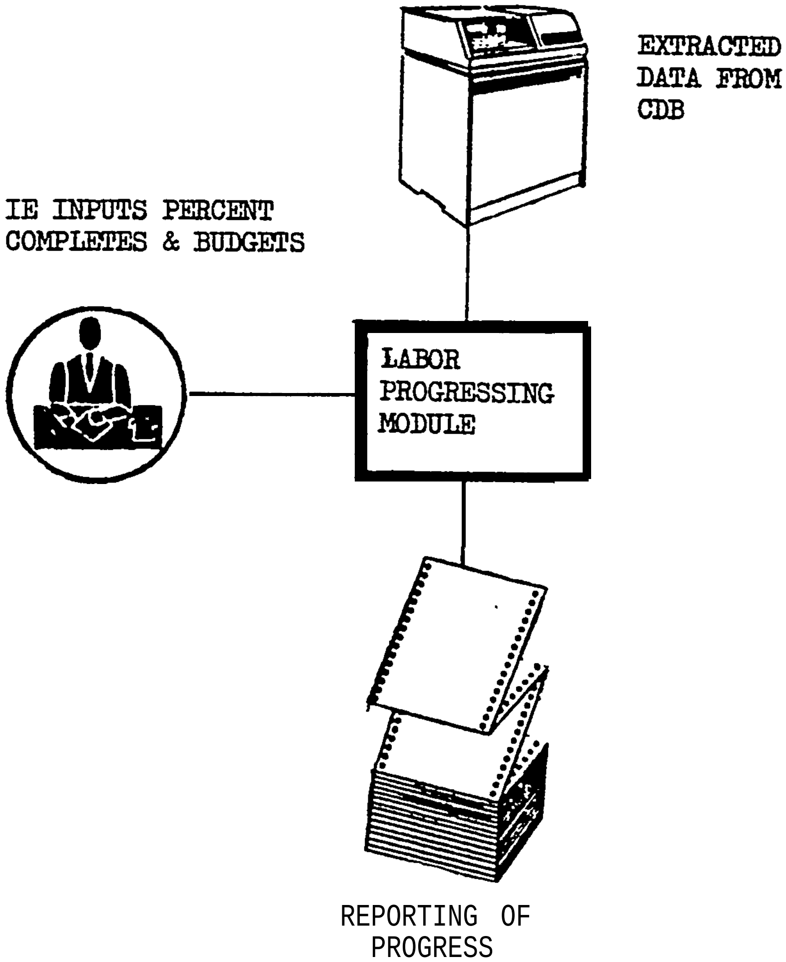
work authorization is summed to three different levels and a percent complete is computed at each level. These percent completes will be used in the next step of the process. In the second step, all supervision and support work authorizations are progressed. Each of these work authorizations is progressed by a pre-determined curve that directly correlates to one of the three levels of percent complete computed for direct construction work authorizations. After all work authorizations have been progressed, reports are generated that reflect progress, performance, and budget overrun/underrun conditions.

C. INTERFACES

The Labor Progressing Module extracts the work authorizations from the CDB Module and computes progress for them. Each progressed work authorization is sent to the Labor Manning Module which computes and time-phases the "to-complete" budget; these same work authorizations are also sent to the Reporting Module where budget performance reports are generated. The Labor Progressing Module computes the percent complete at hull, account, cost center, operation and transmits it to the Reporting Module to be used in contract reporting of budget and cost variances.

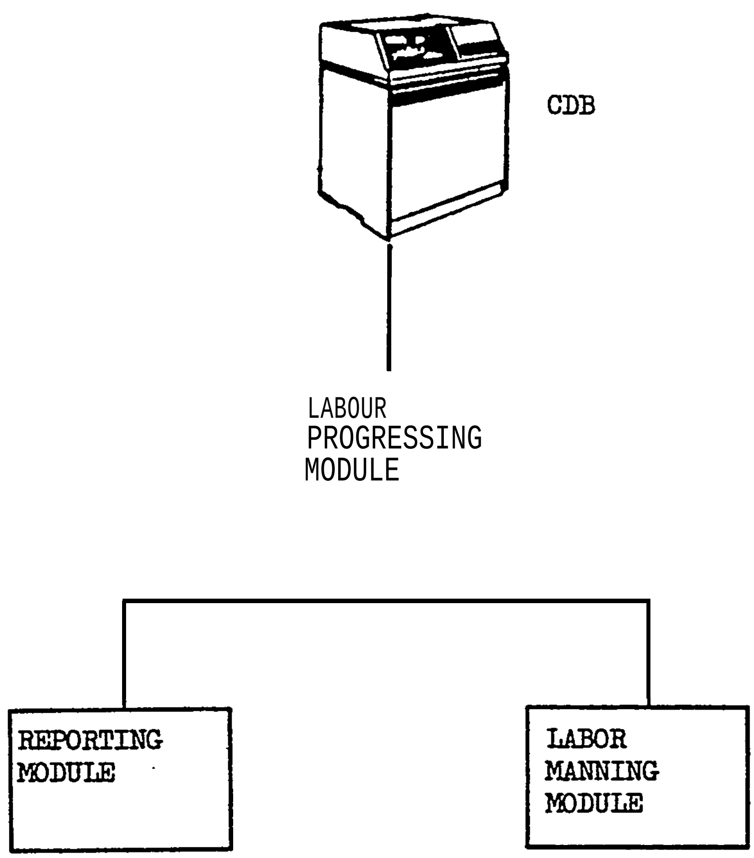
IV. LABOR PROGRESSING MODULE

B. DESCRDTION



IV. LABOUR PROGRESSING MODULE

C. INTERFACES



V. LABOR MANNING MODULE

A. FUNCTION

The function of the Labor Manning Module is to integrate work authorization budgets and schedule dates to Produce a budget manhour spread.

The module is designed to provide mamagement various reports depicting manloading requirements for the cost centers in order to assist management in acquiring the personnel necessary to support ship construction/overhaul.

B. DESCRIPTION

The module time-phases, by hull and cost center, the work authorizations budget among the valid workdays per accounting month as specified by the scheduled start date and the scheduled completion date.

The time-phasing techniques provided by the module are as follows:

1. Linear- all valid workdays which fall within the start date and completion date, inclusively, shall receive an equal pro-rata share of the work authorization's budget .
2. Predetermined Curves - The Manpower Planning Department inputs manloading curves based on historical data. The module time-phases either a cost center to the shape of a curve or construction type work authorizations to the shape of a curve.

3. Proration - The module develops a manloading curve by time-phasing construction work authorizations and then prorates supervision in direct relation to the shape of the curve developed by time-phasing construction work.

The module also has the capability to reschedule delinquent work and recalculates the estimate to complete (ETC) or the estimate at complete (EAC) for not started and in process work authorizations if the user inputs a date specifying the point from which the spread of work authorizations will be started.

C. INTERFACES

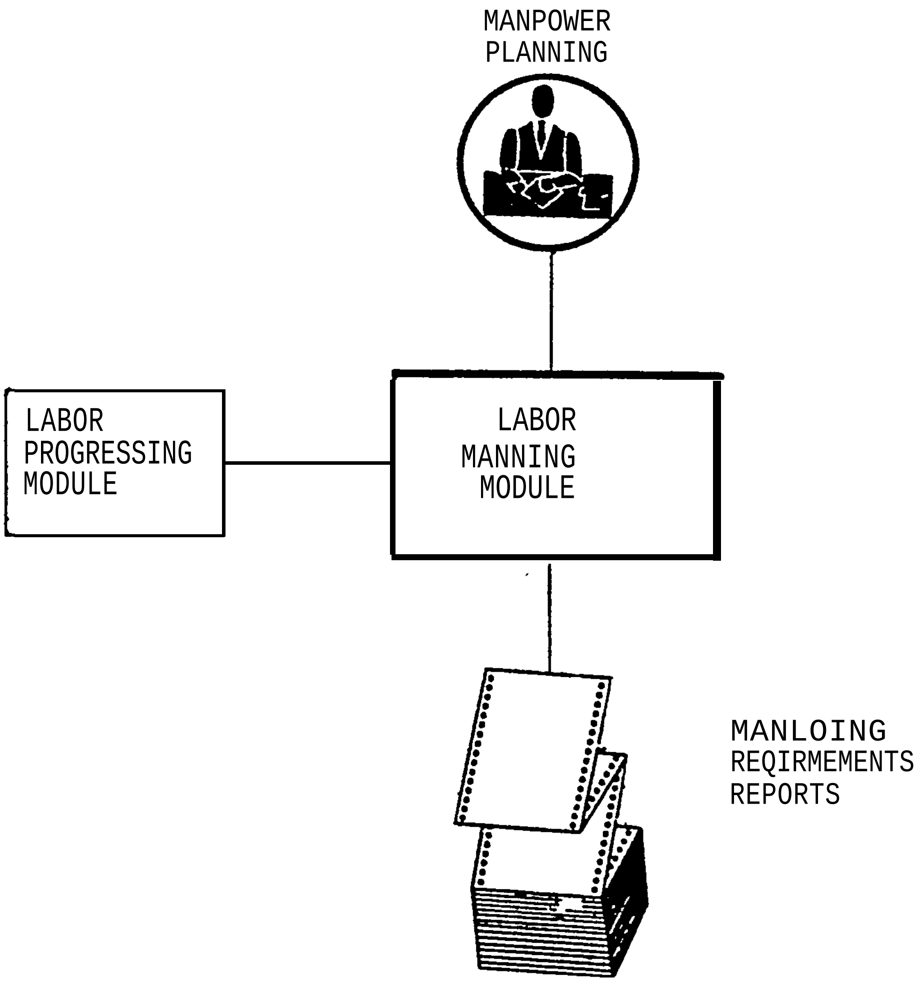
The time-phased manhours developed in the Labor Manning Module are passed to the Contract Performance Reporting Module and the Material EAC Module.

The Contract Performance Reporting Module uses the time-phased manhours to report the budgeted cost to work scheduled (BCWS).

The Material EAC Module uses the time-phased manhours to time-phase stock and raw material in direct relation to the projected manloading that uses these types of materials.

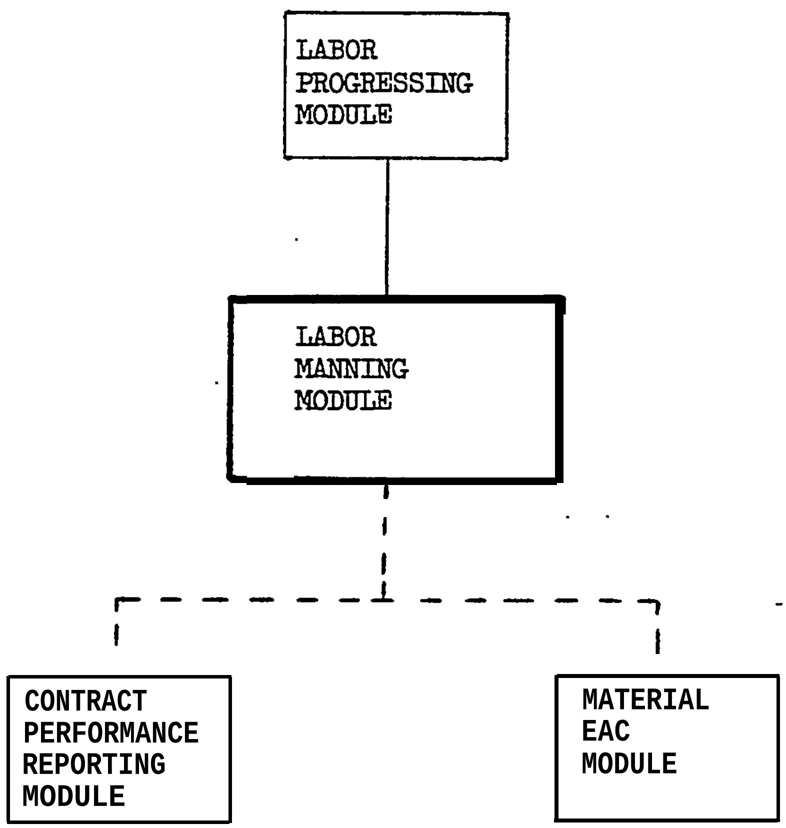
V. **LABOR MANNING MODULE**

B. DESCRIPTION



V. LABOR MANNING MODULE

C. INTERFACES



VI. LABOR RESCHEDULING MODULE

A. FUNCTION

The Labor Rescheduling Module consists of a PERT network for the construction of each hull. All work authorizations for a hull on the CDB are cross-referenced to a PERT network activity in the Labor Rescheduling Module. It is the function of the Labor Rescheduling Module to reschedule work authorizations whenever the schedules of the PERT network activities have changed. These new work authorization schedules are then transmitted to the CDB update program to change the work authorization schedules on the CDB.

B. DESCRIPTION

The Planning and Scheduling Department develops PERT networks of the major activities necessary to support construction of a ship. These network activities are then input to the Labor Rescheduling Module. This module insures that the activity schedules are in the proper sequence and that there is no unused time between the completion of one activity and the start of the next; exception reports are generated reflecting any discrepancies. Planning and Scheduling re-inputs corrections to the network activities until all exceptions have been cleared. Once accurate networks are established, then work authorizations from the CDB Module are brought into the Labor Rescheduling Module and linked to the applicable network activity by a cross-reference number. The schedules for each of the work authorizations are then changed to fit within the network activity schedule.

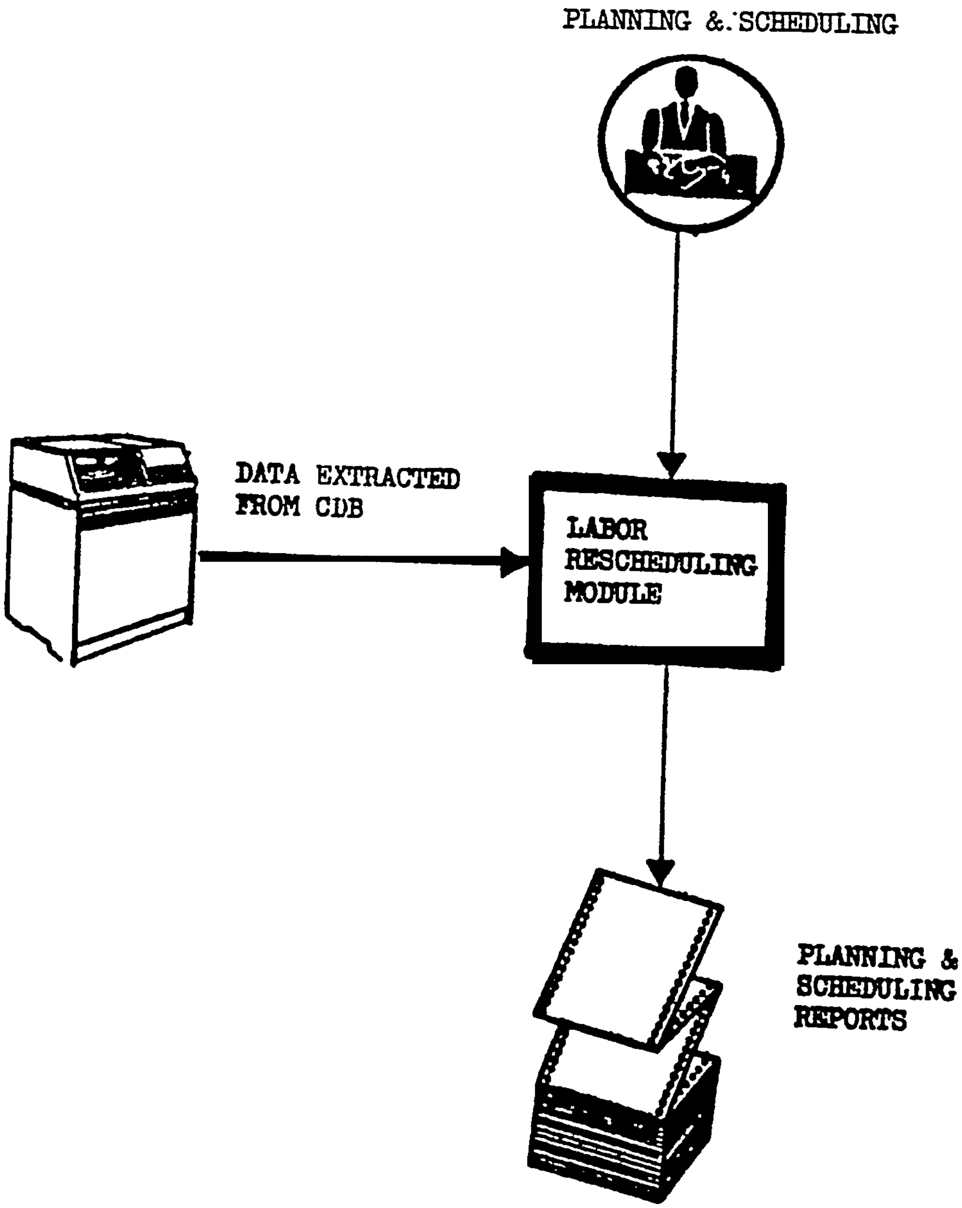
The revised work authorization schedules are then transmitted to the CDB Module for modification of the work authorization schedules on the CDB.

C. INTERFACES

The Labor Rescheduling Module extracts work authorizations with their schedules from the CDB Module, reschedules the work authorizations, and transmits the new schedules for the work authorizations back to the CDB Module.

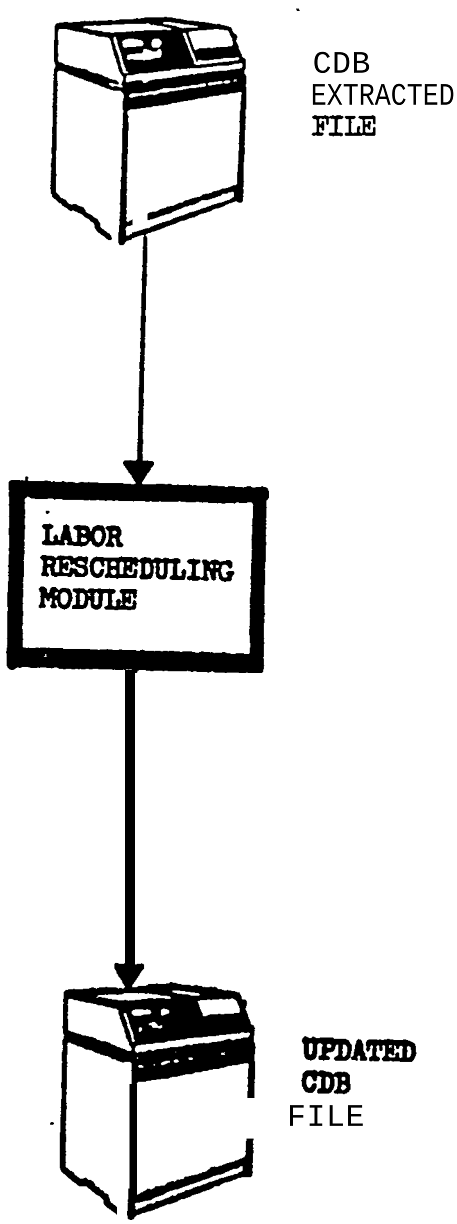
VI. LABOR RESCHEDULING MODULE

B. DESCRIPTION



VI. LABOR RESCHEDULING MODULE

C. INTERFACES:



VII . LABOR REPORTING MODULE

There are more then 365, 000 work authorizations and associated data for approximately 40 hulls, which are in various stages of construc-. tion, stored on the CDB. This large volume of information required to support ship construction prohibits manual tracking, progressing, and statistical analysis. The many segments of data are compiled into various reports specifically designed to meet the needs of Production Control, Planning & Scheduling, Financial Accounting,Industrial Engineering, and the various levels of Ingalls Shipbuilding management.

A. PRODUCTION PLANNING AND CONTROL

Production Planning and Control reports contain production schedule information which is normally displayed by Hull. The nucleus of this reporting module is the schedule analysis segment which provides information relative to the interaction of schedules within one or more hulls. Another important segment of this module is the ability to report between crafts interfacing responsibilities. There are approximately 5O reports available in this module of which any or all of them can be selectively produced on a weekly basis.

B. CONTRACT PERFORMANCE

The Contract Performance reporting module provides both Ingalls management and the Navy current status and the long range plan for fulfillment of contractual requirements. The central source of data is generated via the Labor Manning Module and includes Company Operating Budget and Contract Budget data time phased.

The Contract Budget is used to status and report progress to the Navy while the Company Operating Budget is used by lngalls management to status the detail work to be accomplished throughout the duration of the contract. This reporting module produces approximately 54 separate reports which provide Ingalls management and the Navy the current contract status and the Estimate to Complete contract status.

C. BUDGET PERFORMANCE

The Budget Performance reporting module provides work authorization progress and performance information for Ingalls management; primarily, Industrial Engineering, Quality Assurance, and Operations. Data for this module is generated via the Labor Progressing module and includes Company Operating Budgets, Contract Budgets, and Labor Actuals. Approximately 20 reports are available via the Budget Performance reporting module and are used in evaluating actual progress and performance vs. previously established budgets. Many report sequences and selections are available, thus providing a very versatile reporting system.

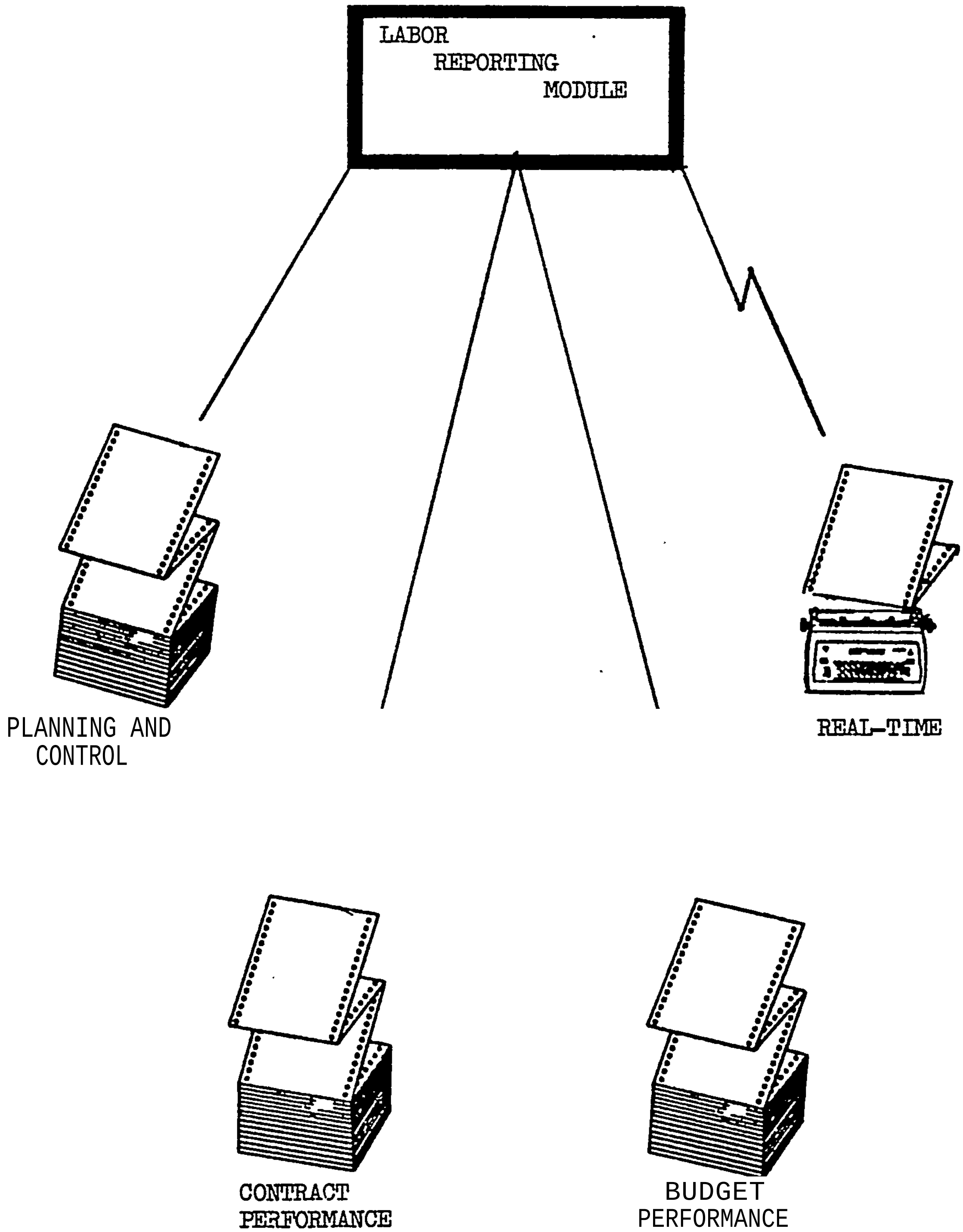
D. REAL TIME

The automated method of building ships at Ingalls requires accurate and timely dissemination of work authorization data to the crafts. A Real Time module is employed which allows immediate access to the Consolidated Data Base for work authorization information. Approximately 60 communication terminals are strategically located throughout the shipyard to support this activity. Training and utilization of these terminals is simplified through an easily accessible on-line

user’s guide. More than sixty different retrievals provide the users rapid access to work authorization schedules, budgets and other pertinent information. Future enhancements include a module which will peemit indirect updating via the data terminals.

This Real Time module is a vital part of the total Ingalls’ Production Planning and Control System and complements the various reporting modules previously described in this presentation.

VII . LABOR REPORTING MODULE



SPCS -- A COMPREHENSIVE SYSTEM FOR SHIPYARD PRODUCTION CONTROL

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and
Ronald Smith
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Mr. Vaughn is General Manager of Technical Services and Product Development. A & P Appledore International specializes in shipyard development engineering covering all hardware and software to the industry. They are responsible for the design of a modern shipyard in South Korea with a 350,000-ton steel throughput potential.

Mr. Smith is a systems analyst responsible for the design and implementation of production control and other systems. He has ten years experience with commercial and scientific systems on mainframes and minicomputers. Mr. Smith has a B.SC. degree with honors in Applied Sciences.

INTRODUCTION

With shipbuilding capacity worldwide well in excess of demand and competition for orders extremely fierce, shipyards must ensure that all resources are used effectively. Each man on the shop floor, each foreman and manager must be able to carry out the work required of him - which means that he must be provided with all the required information on the work to be done and the means to carry it out. He must not receive too much information and the information presented must be in a form which can be readily assimilated.

The competition for orders, quite apart from resulting in shorter lead times, has resulted in shipyards building a wider range of products than was envisaged even a short time ago. For example, a European shipyard which for many years built only VLCCS now markets a range of products from offshore supply vessels through floating factories to large LNGCS. The potential. variety of individual operations within a shipyard in this situation is much higher than in the case of a single product facility. The information channels used in this production system are similarly going to require greater capacity, speed and accuracy.

SYSTEMS DEVELOPMENT IN RETROSPECT

The equipment and hardware in shipyards has, over the years, become more and more specialized. As the variety of products reduced, so physical layouts became more rigid. As shipyards became more organized. so planning departments grew in size and so too did the size of computer planning tools. There was a tendency to centralize decision making, sometimes removing the input which could have been made by first line supervisors. It quickly became apparent that the computer tools were not sufficiently representative of what was actually happening on the shop floor.

In an attempt to become more realistic, they became more and more detailed. For example, the number of activities in a network grew to five and ten thousand and beyond. The updating problems were immense and the technique lost its attraction because it was misused. To redress this situation, full authority was sometimes handed back to foremen and head foremen. Unfortunately, both the product and the shipyard were by now more complex, and there was no way of supplying the required amount of information to enable control to be maintained.

In the situation of over-centralization, the tools used attempted to predict the state of the production system over time without, at the same time, supplying the means to control production. Prediction and reality tended to diverge.

In the situation of over decentralization, the means of control were there, but there was an absence of a clearly stated set of detailed objectives. It is probably true to say that the rejection of both these solutions leaves an organizational vacuum.

ORGANIZATION DEVELOPMENT

An immediate, partial solution is to attempt to align the staff function much more closely to the production organization, giving a typical structure as shown in Figure 1. This reflects the position shown in Figure 2. As successively lower levels of the management hierarchy are studied, the amount of information to be processed grows and the cycle time for control decreases. It is these two, incompatible, factors which render the approach towards increasing centralization of the control of all operations ineffective.

The structure in Figure 1 also has a more subtle purpose. This is to remove the feeling of remoteness, sometimes bordering on antipathy, between 'planning' and ‘production' by combining them at each major level and within each major department in the organization. Thus, at the shop floor, foremen and operations control staff work together as a team,

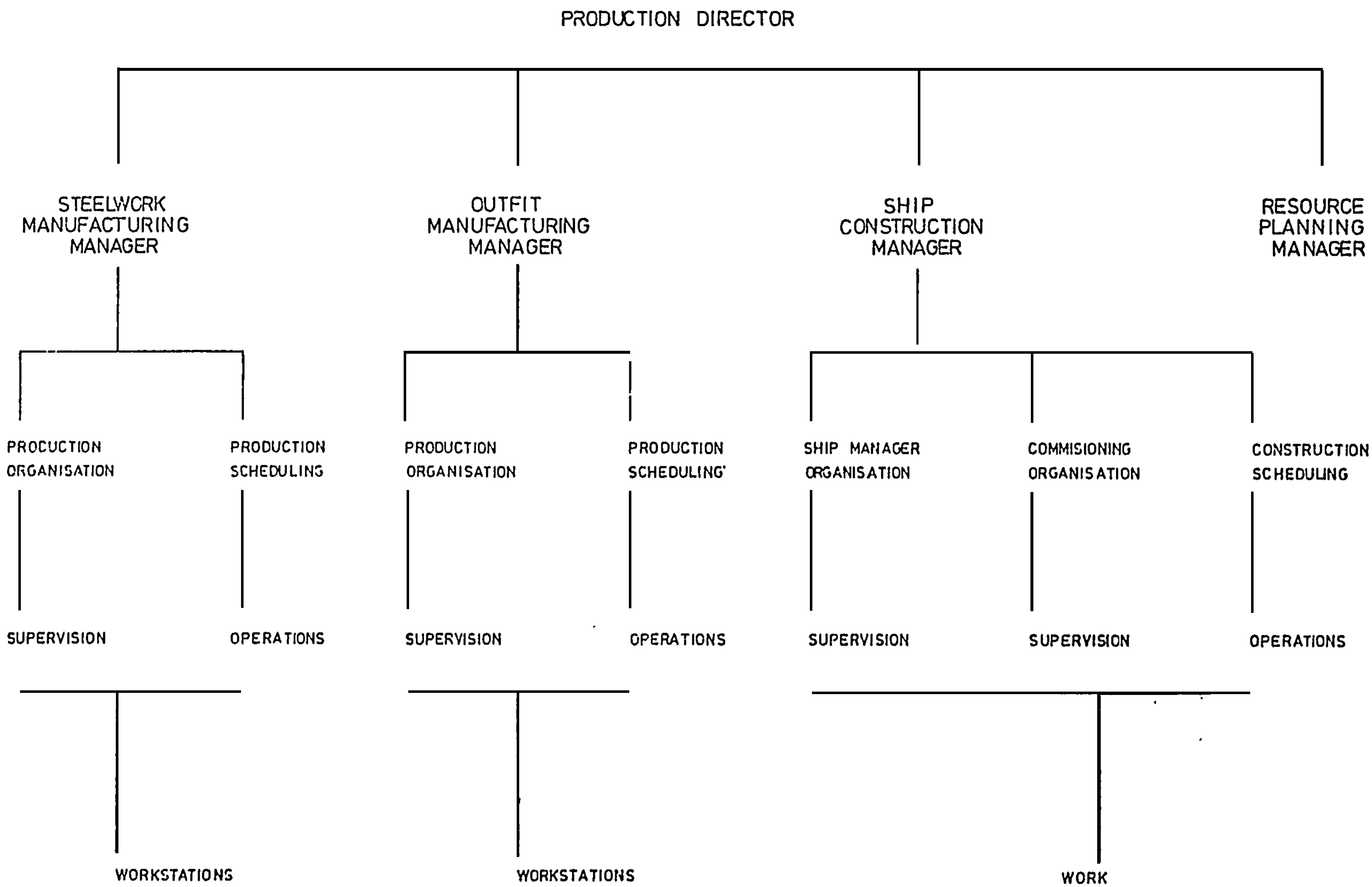

PRODUCTION DIRECTOR
STEELWORK MANUFACTURING MANAGER
OUTFIT MANUFACTURING MANAGER
SHIP CONSTRUCTION MANAGER
RESOURCE PLANNING MANAGER
PRODUCTION ORGANISATION
PRODUCTION SCHEDULING
PRODUCTION ORGANISATION
PRODUCTION SCHEDULING'
SHIP MANAGER ORGANISATION
COMMISIONING ORGANISATION
CONSTRUCTION SCHEDULING
SUPERVISION
OPERATIONS
SUPERVISION
OPERATIONS
SUPERVISION
SUPERVISION
OPERATIONS
WORKSTATIONS
WORKSTATIONS
WORK

FIGURE 1

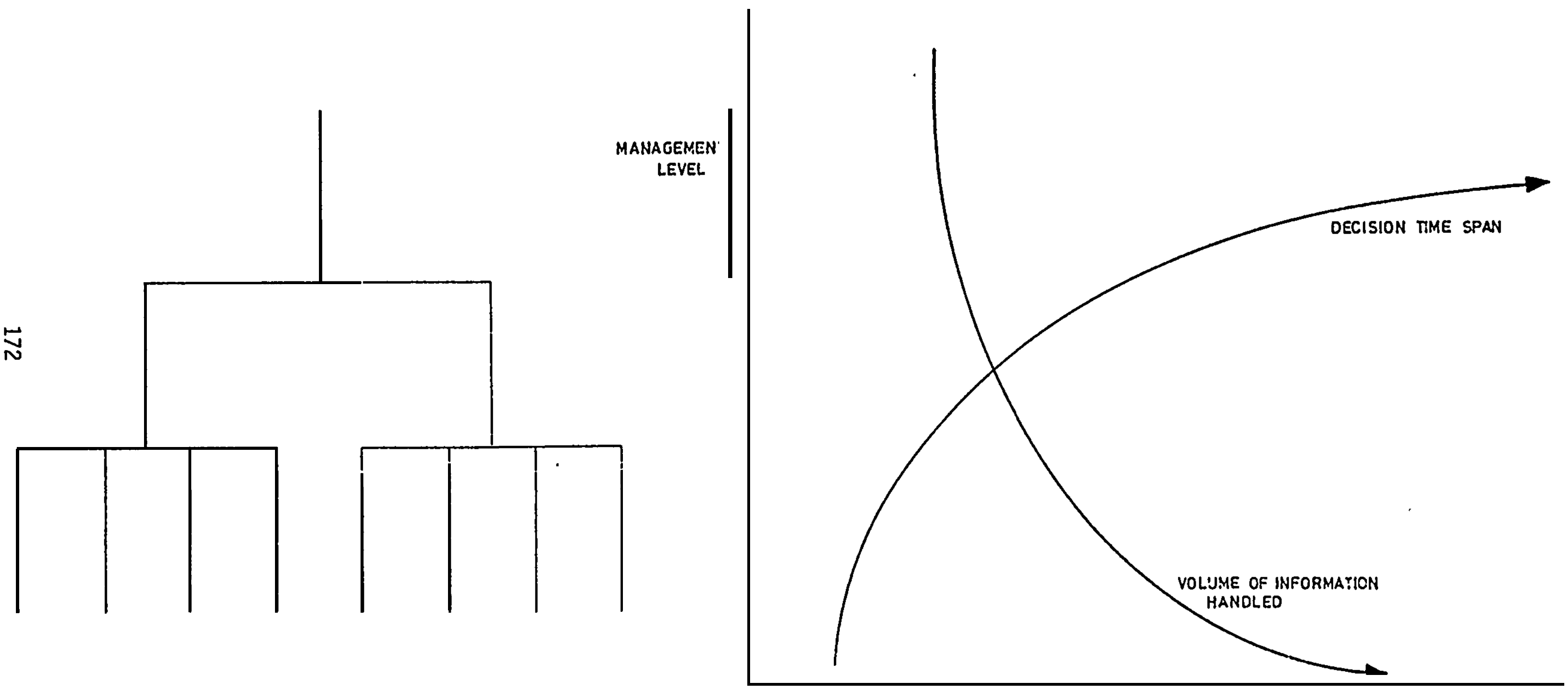

MANAGEMEN
LEVEL
DECISION TIME SPAN
VOLUME OF INFORMATION
HANDLED

FIGURE 2

responsible to the same assistant manager. Assistant managers and production schedulers are likewise juxtaposed and so are production department managers and the resource planning manager.

This organizational concept does not encourage the use of a central main frame computer, and the problem of data transmission and effective co-ordination remains. Looking at production control in this way, in terms of the total information flow within the organization, the case for or against computers can be determined purely in terms of the amount of information to be processed rather than the availability of a particular technique.

In many smaller shipyards, manual procedures are quite adequate. In larger shipyards, especially where the variety of ships produced is high, computer processing is probably essential. In order to preserve the proximity of control procedures to the management they are designed to support, distributed computing, using a mini-computer network, should be considered. In any event, the interface with computer facilities should be designed so that each manager can consider the system from his point of view to be 'his system'.

SCHEDULING TECHNIQUES

The enhancement of production control has been, in the past, and even now is sometimes looked at in terms of the importation of a particular scheduling technique. PERT and CPM are good examples.

Networking suddenly became the cure-all for production control problems. More recently, scheduling packages, often designed for the general engineering industry, were applied. The problem is not so simple.

Scheduling packages of this kind simulate the real world. In the case of networks, the simulation concentrates on the logical relationship between the start and finish of sequential activities. Networking was a major breakthrough. Unfortunately, its success depends on there being a relatively small number of alternative sequences of work. This is particularly acceptable in the case of on-board outfitting where the physical relationship between outfit items often determines that there is only a limited number of alternative sequences. Management can then choose the preferred sequence and draw the network logic.

Where there are large amounts of float or slack, other means have to be found for deciding exactly when an activity shall take place. Often, a solution can be mathematically defined from a resource allocation process. The result may not, however, be optimal and careful study may be required by management of the results of any such process.

Network analysis is totally inappropriate to detailed workshop scheduling where the individual sequences may be determined by a combination of process sequence, batch production and

production line balancing. In some cases, simulation using packages designed for engineering have been used. Success has not been high because the choice between the large num - ber of possible activity sequences is often made by internally generated priorities.

The algorithms used to generate priority may be satisfactory where there is a large number of assemblies prod- uced. This is not the case in shipbuilding. The net result is that the progress made against a schedule issued at the start of a week may determine a different set of internal priorities at the end of a week. The schedule produced for the start of the next week (for which some operations may already be under- way) may differ dramatically from the one expected. Such changes are totally confusing to the shop floor. In short, these scheduling methods are unstable in the shipbuilding context. A new approach is required.

THE CONCEPTS IN SPCS

This rather long explanation of the uses and abuses of production control in the shipbuilding industry helps to explain why SPCS was developed and why it is not just another new package. It is the first attempt to look at the information and control require- ments for the management of production operations from top to bottom.

The assembly flow process of shipbuilding is itself used in the design of an information system, with each module of that system using techniques and procedures relevant to a specific production area. Rather than replacing management decision making, SPCS supports it by supplying the right information at the right place at the right time. The amount of information to be processed will depend on the size and complexity of the ship, the rate of output and the lead time allowed before production.

The use of the information is three-fold. Firstly, the various databases can be interrogated to supply data on the state of all operations. Secondly, the information can be used to assess the feasibility of different strategies, thus limiting schedules to a small number of those which are possible but leaving foremen free to choose the one which is most appropriate. Thirdly, the systems can be interrogated to provide answers to "What if ?" questions. This is particularly important at the corporate planning level where the ever changing scenarios of future orders require the treasury and manpower functions to be able to forecast requirements.

Where a scheduling algorithm is required, it is designed to be uncomplicated and to reproduce the way in which local management would determine priority. In most areas, however, rather than scheduling by simulation (which requires complex algorithms) the time available for a set of tasks is allocated on the basis of a physical scheduling parameter which

can be used to assess performance as well as progress at each work station. This scheduling method allows specific control over inter-process buffer storage levels and major sequences reflecting the overall relationships between assemblies. Minor sequences relating to short term machine loadings are left to the discretion of foremen.

For example, while satisfying the assembly schedule for the ship as a whole, it is possible for foremen to vary the precise sequence of production in the shop to a limited extent, in order that an even work load is maintained in the work shops.

SHIP PRODUCTION CONTROL

The objective of any production control system must be:

- to provide all levels of management and supervision with timely and accurate information that will enable them to contribute effectively to the performance of the shipyard as a whole.

Shipbuilding is a complex process that requires design, drawing, material procurement, manufacturing and construction activities to be co-ordinated. So what, therefore, are management's information needs ? The questions that must be answered by the system will depend upon the level of management under consideration. For example, foremen will need to know:

- What is the next job ?
- What material is required for that job ?
- Is the material available ?
- If material is available, where is it located ?
- Is the technical information available ?
- If material or technical information is not available, what course of action should be taken ?

Managers must be able to answer questions such as:

What work is required from their area over the next time period ?

- What are the budgets for the work ?

- What resources are required ?

- What is the status of work currently in progress ?

- How is each work station performing ?

Senior executive management will need information on:

- departmental performance

- contract status

- contract performance

- resource utilization.

Without information tailored to his specific needs, no decision-taker, whether foreman, manager or senior executive, can function effectively; if not provided, problems will not be solved at the most appropriate level of management, and ultimately the progress of work on the shop floor will suffer. Also, since the shop floor is the main demand center for, and generator of,

information, it is clear that management's information needs must be linked to the shop floor production control system if effective production and corporate strategies are to be defined.

The resulting flow of information is shown in Figure 3.

Production control systems must be designed to co- ordinate all activities carried out in the shipyard, by breaking down departmental barriers and focusing attention on efficient production. Managers and foremen should then be free to con- centrate on the real problems of:

- man management
- cost reduction
- performance improvement
- quality control.

SPCS is a flexible and uncomplicated approach to production control, aiming to supplement management rather than to replace management decision making by black-box decision rules. It consists of a set of inter-tied modules, each of which is executed either manually or by batch computer processing or on-line, depending on local circumstances. The inter-relationship is shown in Figure 4. The modules and their tasks are:

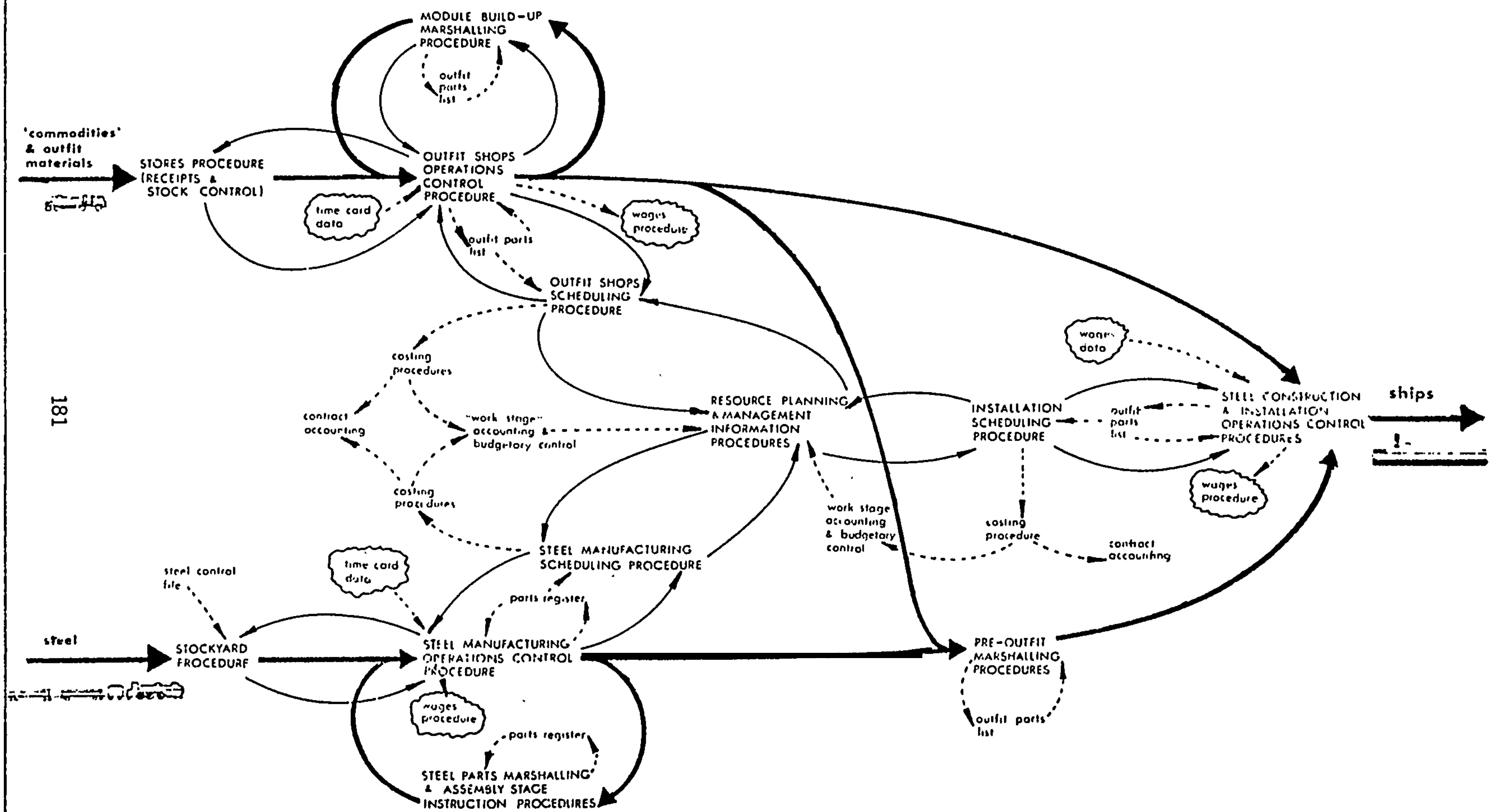


Fig. 3 OVERALL INFORMATION FLOW

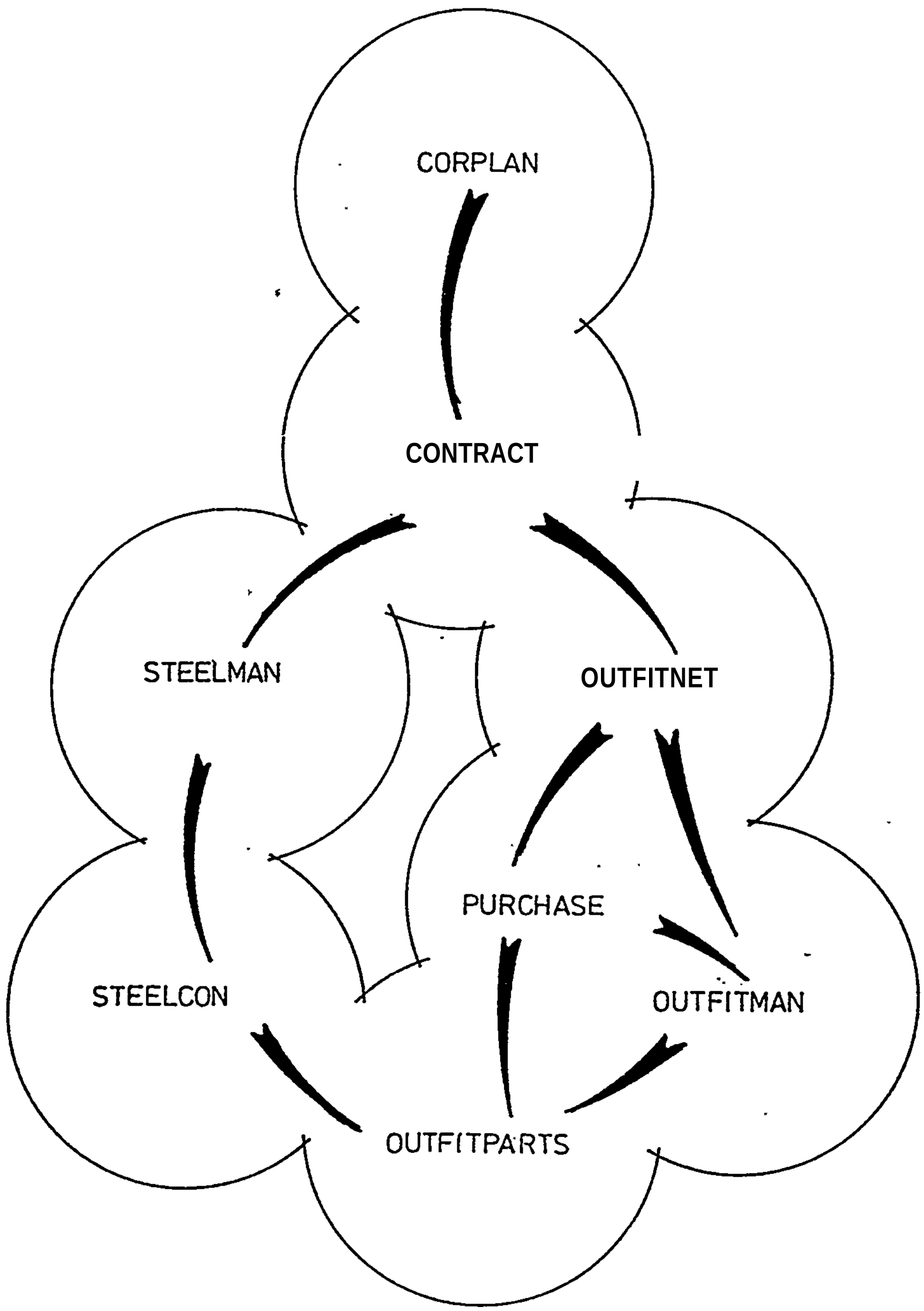

CORPLAN
CONTRACT
STEELMAN
OUTFITNET
PURCHASE
STEELCON
OUTFITMAN
OUTFITPARTS

FIGURE 4

Module	Task
CORPLAN	Corporate planning and scheduling
CONTRACT	Contract scheduling
STEELMAN	Steelwork production scheduling and control
STEELCON	Block assembly and steelwork erection scheduling and control
OUTFITNET	Outfit installation scheduling
OUTFITPARTS	Outfit installation parts control
OUTFITMAN	Outfit manufacturing scheduling and control
PURCHASE	Purchase and stores control

An essential attribute of the system is its flexibility - the version installed in a particular shipyard is specific to that shipyard.

CORPLAN provides a facility for examining the implications of adopting various corporate strategies; the major variables considered are production sequence, labor, availability, labor rates and material prices. The output from CORPLAN is a feasible schedule of dates for keel laying, launch and completion, together with the associated labor curves and cash flow.

CONTRACT is a set of methods and procedures for determining the cardinal date program for each ship production contract. At the heart of the ship production process lies the determination of the erection schedule for the ship, a pivot around which all other scheduling takes place. This module, therefore, is a medium term scheduling tool, allowing the current orderbook to be integrated with the preferred corporate plan. It sets the planning boundaries and constraints within which more detailed scheduling is carried out in subsequent modules.

STEELMAN is designed to solve the problems of steelwork production, scheduling and control. It covers the creation of a plate and stiffener parts database, the control of steel purchasing and delivery and the scheduling and control of steelwork production. Effective use can be made of computer based information handling systems, extending to real time control where appropriate. The detailed design of this module will reflect the organization of work at shop floor level, and the definition of work stations.

STEELCON is a set of procedures for the scheduling and control of block assembly and ship erection activities. It converts the erection scheduling segment of CONTRACT into detailed work station schedules and it interacts with STEELMAN by providing a unit demand schedule. It also provides information to OUTFITNET with regard to completion of onboard zones.

OUTFITNET is approach to the problem of scheduling outfit installation work. The concept of work station organization is applied to onboard installation, providing a facility for predicting both bought-in and manufactured material requirement dates - essential to the efficient control of outfit material to the ship, and to the organization of the purchasing and manufacturing functions.

OUTFITPARTS provides information on the availability and location of installation parts. Technical and production data is merged with the ship production schedule, to provide material requirements. This allows management action to be concentrated on delinquent items.

OUTFITMAN is a combined parts listing and shop scheduling system for manufactured parts. It provides a technical database for piece parts and produces shop schedules for manufacture and assembly to match the demand for installation parts.

PURCHASE provides a means of ensuring that material is available in the shipyard to support the building program. It enables bought-in materials to be effectively progressed and provides timely information on the availability of outfit material to production departments.

Production control systems are only a part of the overall shipyard operating system. SPCS modules have been designed to handle and process technical information. Clearly, the format of technical information must be. decided on the basis of the needs of production. However, the fact that production control must process the information should also be considered.

An important output from SPCS is management information. Management information reports are prepared from data collected on the shop floor and therefore consideration has been given to the methods of data collection and processing. Solutions to these problems are part of each SPCS module, together with management information report formats.

The accounting function must also receive information from production departments on work completed and manhours used to enable payroll systems to operate, to revise forecasts and prepare operating statements. SPCS modules are designed to ensure an effective interface between production and accounting functions.

SAVINGS AND BENEFITS

Having established the necessity for production control, the question most often asked is - "[What savings will be achieved by implementing a production control system ?" The savings made will depend upon:

a) the situation in a shipyard before implementation

b) the commitment given by shipyard management to making systems work

c) the effort put into training and familiarization.

In order to identify areas in which savings can be made, consider an alternative statement of the objective of a production control system. It is:

- to ensure that there is a continuous and correctly sequenced flow of work through manufacturing and ship construction work stations.

This means that by providing information on material requirements and status, it is possible to control material and information flows so that neither the man on the shop floor, nor his foreman has to search for the "next job". Therefore, idle time on the shop floor will be substantially reduced and quality levels improved because of a more effective use of supervision. And if the dimensional accuracy of fabricated units is improved, savings can be made at the building berth stage.

A further point to be considered is the job satisfaction of shop floor personnel. Frustration builds up when men find themselves idle because of material or technical information shortages, and this frustration can be a contributory cause of absenteeism and high labor turnover.

A good production control system will therefore enable resources, labor and equipment to be used efficiently. But if it is to be effective it must be implemented on a broad front. For example, it is not practicable to introduce a system to schedule steelwork production in isolation; for such a procedure to be effective, it must receive inputs from the technical departments - drawings, material lists and key date information from central or resource planning. In addition, the procedure will need fee dback on work completed and hours worked, in order to verify scheduling parameters and prepare useful management reports.

It was with all these considerations in mind that A & P Appledore designed their ship production control system, now known as SPCS.

SPADES' PROGRESS IN SHIPBUILDING

Vincent H. Nuzzo
Avondale Shipyards
New Orleans, Louisiana

Mr. Nuzzo is the Assistant Superintendent of the Mold Loft and Director of Numerical Control. He has 24 years of experience in the mold loft at Avondale and has spent the last ten years in developing the usage of numerical control.

Presently, Mr. Nuzzo serves as the Chairman of the SPADES Users Steering Committee.

In the past 3½ years, the SPADES System has proven itself to be a viable, effective design and shipbuilding tool. This system is now being used by 4 major shipyards in the United States:

Avondale Shipyards, Inc.
National, Steel and Shipbuilding Co.
Lockheed Shipbuilding and Construction Co.
Livingston Shipbuilding Co.
McDermott Shipbuilding Co.
(dormant at this time)

Not only does SPADES serve as a host system for these yards, but it is also utilized by Cali and Associates service group to fair hull lines, do design calculations and the N.C. lofting work for several small U.S. shipyards.

The SPADES system has been used to construct various types of ships and steel structures:

Shipbuilder: Avondale Shipyards, Inc.
Type/Class of Vessel: 86,000 DWT 'EXXON' San Francisco Class
125,000 M3 LNG Methane Delta Class
164,000 DWT 'SOHIO' Class Oil Tanker
56,000 DWT Product Tanker
*LASH Cargo Vessel
ODECO Semi-Submersible Oil Rig
SEDCO Drill Rig
WESTERN Drill Rig
ZAPATA Drill Rig
300 Ft. Oil Barge
300 Ft. Deck Barge
450 Ft. Deck Barge
470 Ft. Deck Barge
195 Ft. Chemical Barge
Offshore Tank Barge
500 Ft. Ore Carrier Barge
900 Ft. Floating Dry Dock
AO Class Navy Oilers

Shipbuilder: National Steel and Shipbuilding Co
Type/Class of Vessel: 190,000 DWT 'SAN DIEGO' Class
AD Class Navy Destroyer Tender

Shipbuilder: McDermott Shipbuilding Co.
Type/Class of Vessel: 126 Ft. Harbor Tug

Shipbuilder: Lockheed Shipbuilding and Construction Co.

Lofted by: Lockheed Shipbuilding and Construction Co. and Cali and Associates, Inc.

Type/Class of Vessel: AS-39 Class Sub Tender

Shipbuilder: Livingston Shipbuilding Co.

Lofted by: Livingston Shipbuilding Co. and Cali and Associates, Inc.

Type/Class of Vessel: GLOMAR 40 Class Drill Ship
DIAMOND ‘M’ Class Jack-up Rig
429 Ft. x 65 Ft. x 21 Ft. 6 in. product Carrier

Lofted by: Cali and Associates for,

Atlantic Marine, Inc.

Type/Class of Vessel: 79 Ft. Stock Trawler

Kings Craft Corporation

Type/Class of Vessel: 75 Ft. Aluminum Home Cruiser

Marinette Marine Corp.

Type/Class of Vessel: LCU-1671 Class Landing Craft
LCM(6) Class Landing Craft
T-ATF Fleet Tug
36 Ft. Mini-ATC
150 Ft. ‘ARTUBAR’ Tug Boat

McDermott Shipyard

Type/Class of Vessel: 180 Ft. x 40 Ft. x 14 Ft. Offshore Supply Vessel

Peterson Builders, Inc.

Type/Class of Vessel: 178 Ft. Patrol Gunboat (PPG 1)

Service Machine and Shipbuilding Co.

Type/Class of Vessel: 136 Ft. Supply Tug

Steiner Shipyard

Type/Class of Vessel: 75 Ft. Stock Trawler

Tacoma Boatbuilding Co.

Type/Class of Vessel: 106 Ft. U.S. Navy Sewage Waste Offloading Barge
140 Ft. U.S. Coast Guard WYTM Cutter

Tampa Ship Repair and Dry Dock Co.
Ingalls Iron Works Co.

Type/Class of Vessel: 13,500 DWT Bulk Coal Barge

Toche Enterprises-Div of Vickers Enterprises

Type/Class of Vessel: 121 Ft. Tug Boat
170 Ft. Offshore.Supply Vessel

The major shipyards that utilize SPADES and Cali and Associates have organized a user group. Annual two-day SPADES user meetings are held in January of each year to discuss problems and improvements to the system. The SPADES steering committee meets just after the user meeting and again in June (in conjunction with the REAPS meeting) to make official decisions on problems improvements or changes. At these sessions, priorities for Cali and Associates to work toward are established. A problem identification form and a suggestion and improvement form were designed and adopted with a procedure for informing Cali and Associates and all SPADES users about changes or problems within the system. Cali and Associates assigns a unique identification number to these forms and submits comments. The Steering Committee serves as a catalyst to Cali and Associates for constant improvement of the SPADES System.

Since the original introduction at one of the earlier REAPS Symposium's some new features added to SPADES include:

PART GENERATION

A Sub* command which allows the coder to store a routine or operation for later recall by other programmers. This is a powerful tool when used in conjunction with other new features in the system to eliminate duplication of programming effort.

Logical if's, jump and entry commands allow the coders to perform check operations and shorten programs. This provides the capability of doing things in the SPADES System that could only have been accomplished with FORTRAN.

PTNO, the save point routine under an identification number for-later recall,was expanded to allow for 500 points. In addition,all points are in the data base with x, y and z coordinates for easy use in any view.

Three dimensional commands such as distance 2 allows us to save the distance between two x,y and z points in space, and a triangulation routine now enables the coder to develop any

odd contoured parts other than shell plate and decks which are already a part of the System.

Expansion factors automatically expand the part in the x,y or z dimension to allow for shrinkage due to welding.

Part separation allows the programmer to do an entire bulkhead, web, deck, etc., and later use part separation to add the seams as indicated on the Engineering drawings.

The use of skewed planes has been expanded. We can now call a plane through the hull lines at waterlines, buttocks or skewed at any angle and also get the intersection on that plane with loaded stringers and loaded surfaces such as decks, longitudinal bulkheads, girders. This feature was especially established to handle CANT frames.

The template option will provide end cut templates for stiffeners, both Web and Flange from the drafting machine for stiffeners and longitudinals. These templates are used in conjunction with the frame bending output for formed members.

The SPAC module is a production control development. This keeps track of stiffener lengths, part weights, centers of gravity, templates and burning information by assembly.

NESTING

Automatic center punching and hole commands let the system decide on the best sequence for these operations on burning tapes.

Tabs are programmed into burning tapes with tabs on holes generated automatically according to the hole size.

Tape weld feature allows the nester to shift a contour on a part to allow for the gap necessary for Tape Welding.

ON-LINE DATA ENTRY AT PORT WELLER

Jesse Harkey
Port Weller Dry Docks
St. Catharines, Ontario, Canada

Mr. Harkey is Computer Systems Manager responsible for the AUTOKON system, N/C programming and system development. In the past, he has been loft superintendent, N/C supervisor and an N/C programmer.

In March of 1976, the decision was made at Port Weller Dry Docks to purchase an in-house computer system to expand our use of computer programs and to update our present systems. At that time two systems were in operation at Port Weller. The accounting and labor distribution programs were executed on a Litton-McBee paper tape oriented computer system, and the production planning and control, numerical control, and design programs were executed on a UNIVAC 1108 time sharing system using a remote batch terminal for data transmission.

Once the decision had been made to purchase the new computer system, an analyst with a broad knowledge of systems hardware and software was hired by Port Weller to purchase and implement the system. After about three months of investigating different systems, the decision was made to purchase a Varian model V-76 computer.

The new system had to be capable of multi-processing COBOL and FORTRAN application programs, simultaneous Univac communications, and on-line data entry. The Varian was chosen because it met these criteria, and its cost was within Port Weller's budget.

The following are some of the features of the new system:

- 128K words memory
- 2 pages writeable control storage
- floating point processor
- 93.4 million character disk storage
- 9-track magnetic tape unit
- 600 line per minute printer
- 75 CPS paper tape punch
- COBOL and FORTRAN compilers
- 1004 emulation
- 7 CRT's for on-line data entry

At the present time we have CRT's located in five different departments at Port Weller:

- Production Planning and Control
- Estimating and Design
- Stores Inventory Control
- Computer Systems
- Mold Loft

Production Planning and Control uses the CRT for creating, correcting, and updating local files for transmission to the Univac 1108 for processing the Material Requirement planning System and the weekly production progress report programs. The Estimating and Design Department also uses the CRT for editing their files for submission to the 1108 to process their ship design and calculation programs.

Stores Inventory Control uses an entirely different concept for entering data to their disc files. The ADD, REPLACE, DELETE and FIND commands are used to make the appropriate changes to their data base.

Computer systems programmers use the CRT for debugging application programs and for looking at files of other users to give assistance with user problems.

Input to AUTOKON programs is handled the same as card input. Once the AUTOKON program has been punched, the programmer is given an 80/80 listing of his program for validation. If there are corrections or changes to be made to the manuscript, he/she simply makes the change on the listing and returns. it to the data entry operation for updating the file.

The addition of software for accounting and labor distribution is now in progress and will be implemented in January, 1978. That department will have a line printer and a CRT for their input and output.

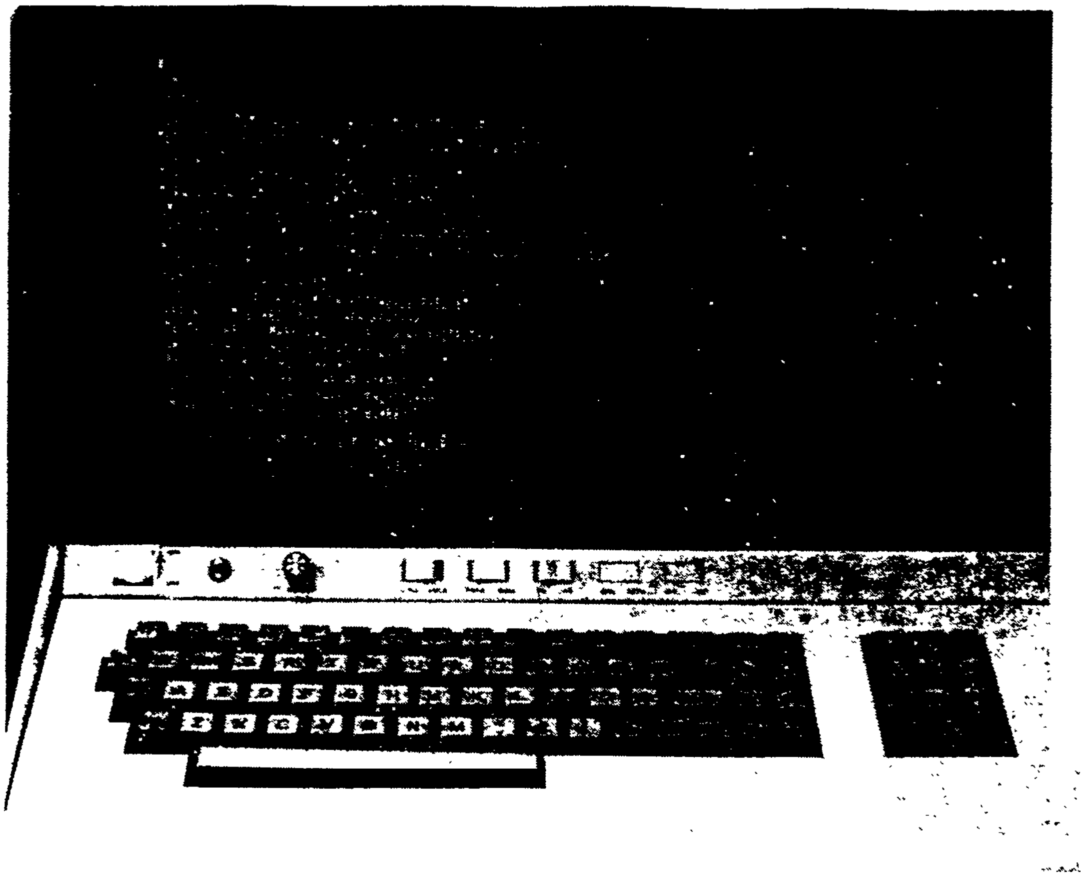
The text editor is an essential tool in on-line data entry. With the editor, we have the capability of creating, deleting, correcting, concatenating and queuing files to be submitted for execution on the Varian or transmitted to the Univac 1108.

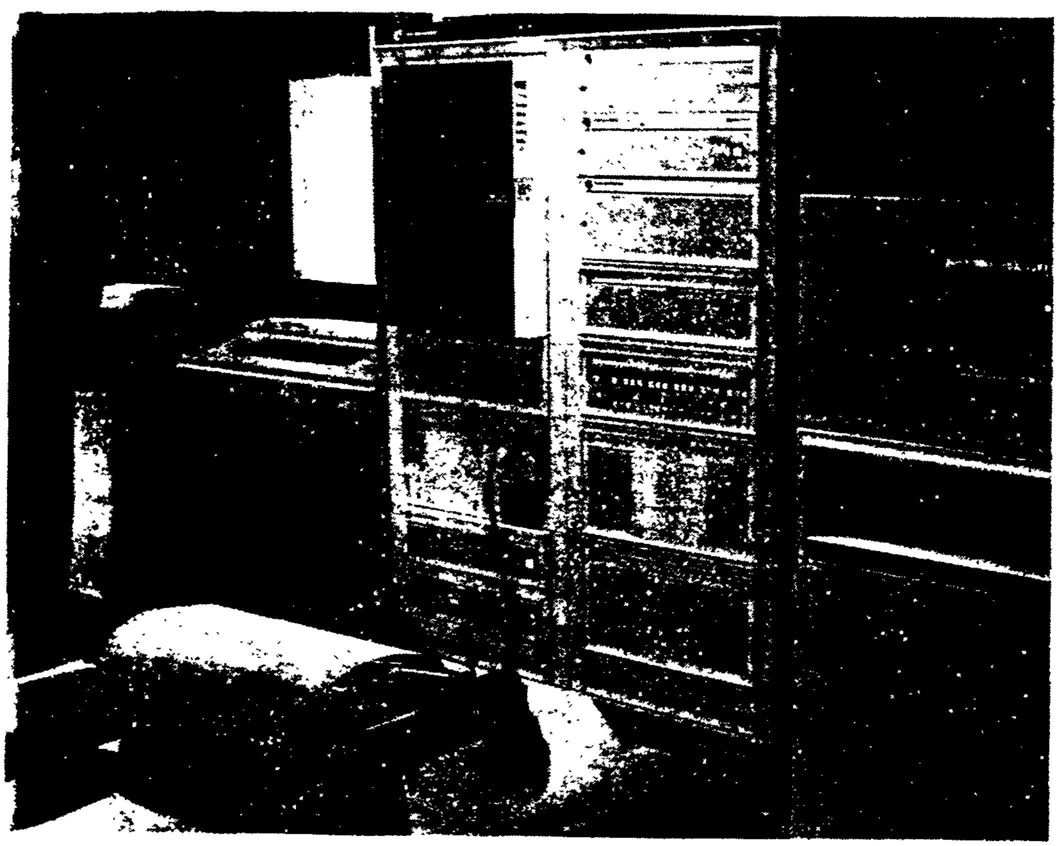
In editing an existing file, we have the following options:

- Deleting a specified number of lines
- Replacing a string of text within a line
- Finding a string of text in a file
- Moving the cursor forward or reverse a specified number of lines
- Adding a line of text
- Tabulating
- Displaying column numbers
- Changing the file name
- Listing a file by each line or page, or in its entirety
- Permanently storing or aborting the file.

The use of on-line data entry to permanent disc files has proven to be faster and more efficient for handling computer programs. It has eliminated the need for massive storage files necessary for storing punched cards. We have also eliminated the mechanical card punch and card reader and replaced them with the electronic CRT.

We at Port Weller believe that our new computer system has greatly improved our-computing capabilities. We do not pretend, however, that this is the ultimate for ourselves, and we will continue to investigate new ways to enhance our use of computers in production, accounting, and management.





THE BETHLEHEM DAMAGED STABILITY PROGRAM

Francis J. Slyker
and
Bruce G. Bohl
Bethlehem Steel Corporation
Sparrows Point, Maryland

Mr. Slyker is responsible for preliminary systems design and computer applications. He has a degree in Naval Architecture and Maring Engineering from the University of Michigan.

Mr. Bohl is a programmer analyst on engineering applications, including AUTOKON support and maintenance. He has a B.S. degree in Engineering from Widner College, Chester, Pennsylvania.

For the last ten years, commercial shipbuilders have had to make frequent and extensive damaged stability investigations. To accomplish this we have developed the program that we are about to describe.

By way of background, passenger vessels have had to meet formal damaged stability requirements for many years. Originally these were not too difficult since the requirements were in terms for which the conventional concepts of statical stability were valid. Subsidized general cargo vessels usually have had to meet similar requirements. Tankers on the other hand, never have had to. Their high survivability after damage was inherent in their extensive subdivision. However, since the early 1960's there has been a trend toward fewer and larger tanks in these vessels. The ability to survive damage has been reduced accordingly.

With the 1966 Load Line Convention there came a new concept to commercial ship design practice. All vessels' are now required to have a degree of survivability after damage. This ability is considered to be implied in vessels with high freeboard. However, it has to be demonstrated on low freeboard ships such as tankers, if they lack extensive subdivision.

There was a new twist to these requirements of particular significance. Submergence of part of the freeboard deck after damage was accepted for the first time. the two limitations being a maximum angle of heel at equilibrium and the provision that no openings be submerged through whichprogressive flooding might take place. If any part of the deck is submerged,.the conventional statical stability concepts are invalid. Therefore, we were forced to begin making damaged righting arm calculations. Subsequently, this became a requirement. Recent oil tanker, chemical tanker and liquefied flammable gas carriers all have requirements for minimum range of stability and residual righting arm after damage.

A further complication exists for tankers. These vessels have to be examined for bottom damage to the cargo spaces. This can easily involve four or more tanks, two center and two wing. Further the regulations for tankers have been interpreted to require that all tanks be considered initially empty. This condition generally does not work. Therefore, the amount of liquid cargo that has to be included in any combination of damaged

tanks in order to survive has to be determined. A similar problem exists with pairs of wing tanks particularily on inherently less stable double bottom ships.

As a solution to these new problems, Bethlehem CTD began the development of a damaged righting arm program back in 1969. The data base consists of a mathematical model of the ship and its compartmentation. Calculations are made on the constant displacement principle. In this respect, damaged compartments are considered as no longer part of the buoyant ship. Net Centers of buoyancy after damage are calculated at the equilibrium draft and trim for each angle of heel. From these a righting arm curve can be constructed. Similarily, for a particular combination of damage and vertical center of gravity, an equilibrium condition can be found. Alternatively, to avoid submerging a particular point on the ship, the maximum acceptable KG can be determined.

The "run off" of cargo has been generally ignored to date because in present applications it usually represents an improvement to the damaged condition.

This program was developed over the years with numerous modifications. It has been the basis of all recent Bethlehem submittals for approval.

The Damaged Stability Package consists of several modules, each performing a unique task.

The first Damaged Stability module, DAMAGE O, performs the following tasks:

1. Given initial displacement and LCG, and compartments to be flooded, the program will compute an initial VCG such that equilibrium after damage will not submerge input limiting points.
2. Similarly, the program may be directed to find an equilibrium waterplane for a fixed VCG and report the status of any input limiting points.
3. A righting arm curve for the damaged ship may be produced either commencing at the equilibrium heel or at a user defined angle and terminating also at a user determined angle. Constant diS- placement with a zero trimming moment is maintained at all angles.

4. The program can be directed to output, for a single draft, trim and heel, all buoyancy and lost buoyancy values for the damaged ship. This option may be used for producing capacities for any compartment designated to be damaged. With this option and the interim print option, the details of waterplane intersections with a compartment can be made available.

The basic steps taken to define a damaged stability problem are as follows:

1. Define a hull form as would be necessary to perform hydrostatic calculations.
2. Define a universe of compartments for the ship based on current arrangement or various alternative arrangements.
3. An option in the input is the definition of limiting points. These points, locatable in 3-space, enable the user to define a margin line or other points of interest to the user. The program will provide waterplane information at each of these points indicating if they are submerged.

4. Generally, to specify a damaged condition:

A. Indicate an initial draft and trim (heel assumed O.O) or a displacement and LCG; either combination provides the displacement and longitudinal center which must be 'balanced' by the program.

B. Indicate the compartments which must be flooded. A compartment will flood if any of its boundaries are intersected by the waterplane. Specify the permeability of the damage compartment and if applicable, the percentage the tank was initially filled prior to damage. Compartments may be grouped in the input so that their total volume and centers will be output as a single entity in addition to their individual properties.

C. Indicate the type of calculation, equilibrium, R.A. curve, etc.

D. Indicate the tolerances on displacement and on longitudinal and transverse righting arms with which to "balance" the ship.

E. Indicate the VCG (if not to be output) including the free-surface effects.

The output for an equilibria condition or for each heel angle R.A. curve consists of the following items:

1. Final Draft, Trim and Heel
2. Intact Hull Properties (as in hydrostatics)
   - displacement and centers of buoyancy
   - bonjean information at each defined section of the ship
3. Damage Compartment Properties
   - flooded volume and centers (if a compartment is partially full initially, the flooded volume is the amount in addition to that already in the tank)
4. Total Flooded Properties
   - sum of all damaged compartment properties
5. Remaining Intact Hull
   - displacement and centers of buoyancy of damaged ship
   - residual righting arms, give the user a report of ‘balance’ on the ship with respect to input tolerances.
6. Dispostion of Limiting Points
   - position of each point with respect to waterplane.

The second of the two damaged stability programs is DAMAGE 1. It was written with tanker loading restrictions in mind.

DAMAGE 1 has two functions:
The first is to compute the amount of cargo which must be present in a compartment prior to damage. This limits flooding in such a way that at equilibrium the lowest of the input limiting points is tangent to the waterplane.

For this type of problem the user specifies one or a series of compartments, all initially empty, to define the damage condition. The program will, based on the input order, determine which compartment must be partially filled to limit heel.
The second function of DAMAGE 1 is to find the maximum intact draft (or displacement) such. that with damage to one or more empty or partially filled tanks, the equilibrium waterplane will be tangent to the 'lowest' input limiting point.

These steps to define a damaged condition for the DAMAGE 1 program are similar to those of DAMAGE O, only the options have changed. Output is also similar in format and information to that of DAMAGE 0.

The DAMAGE O and DAMAGE 1 programs use files which have been created by other lead modules.

The SHIPIN program builds the intact hull data file for the damage programs. (See Figure 1.)

The intact hull can be coded by hand or, with the use of another damaged stability module, PRELDAM, can be produced semi-automatically from a PRELIKON Database. This provides a convienent transfer medium from the Autokon E-file. (See Figure 2.)

The intact hull is defined by a series of sections, forward to aft; their spacings determine the type of integration used in the damaged stability programs on the bonjeans. over that portion of the ship. There are four types of integration available: trapezoidal for *a* single unique spacing; Simpsons 1-4-1 for two equal spacings; Simpson’s 3\8’s rule for three equal spacings. The fourth is simply a double Simpson’s 1-4-2-4-1 for four equal spacings. The damged stability programs will ‘look-ahead' at the spacings to avoid a trapezoidal; if there are five equal spacings, a 3/8’s and a 1-4-1 are performed.

In order to provide exact ends at all waterlines for volume integration of sections, a Zero Bonjean Area boundary is defined to physically limit the extent of the hull .

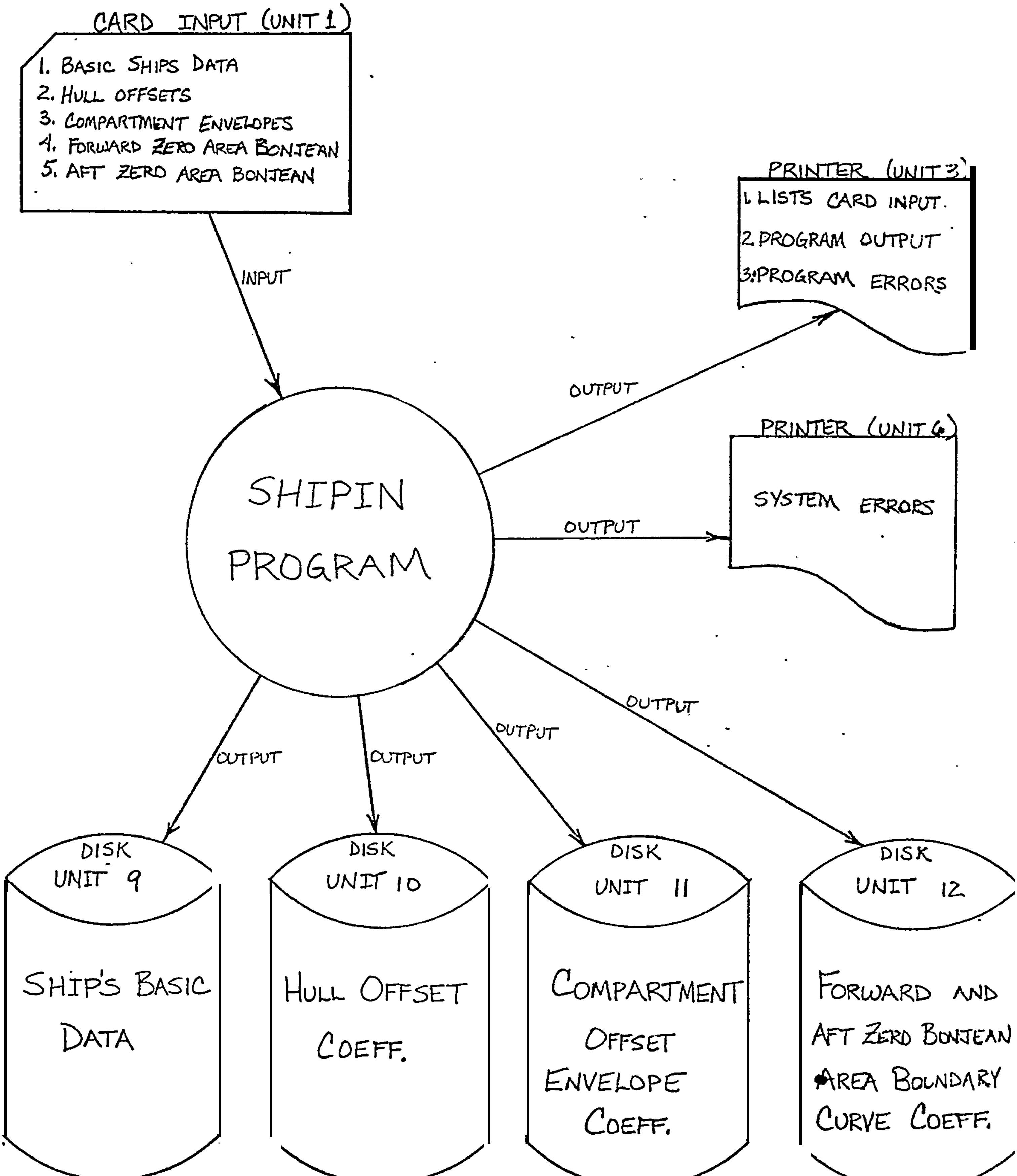


FIGURE 1
SHIPIN INPUT AND OUTPUT

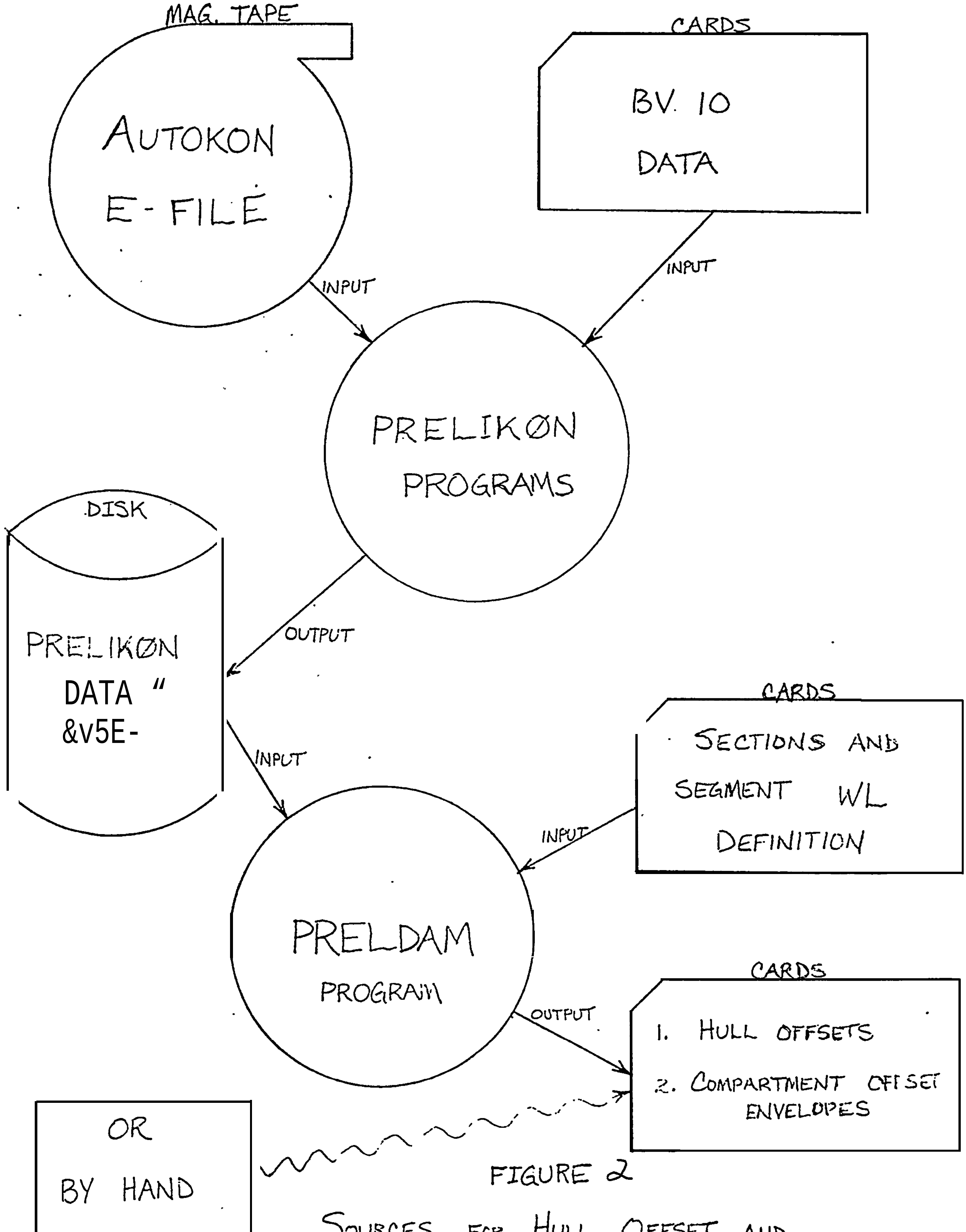


FIGURE 2

SOURCES FOR HULL OFFSET AND COMPARTMENT OFFSET ENVELOPES

Each section defines a transverse molded hull outline from baseline to above deck at center and is described by several piece-wise continuous polynomials or segments. Although the slope is not guaranteed at each segment boundary, the error is not significant to calculations.

The segments are allowed to be of 1st to 3rd order, using equal vertical spacings within each segment. Choosing the right type of polynomial for a given area of the ship assists the accuracy of the mathematical model.

The bonjeans for each section are computed by integrating the segments which are of the form:

$$Y=A_o + A_1 X + A_2 X^2 + A_3 X^3$$

Adjustments are then made for trim and heel at each section. The result is an underwater plane bonjean curve for the molded hull at the current draft, trim and heel. This curve is integrated in the damaged stability programs, according to the previously mentioned method, to produce a molded volume.

Program CMPRTMNT is the final program which provides files for the damaged stability programs. (See Figure 3.)

Several types of compartments are allowed. The first is geometric shapes: CYLINDERS & SPHERES which are defined by their axis of rotation or center point, radius and, in the case of cylinders, the ends.

Another way of defining a compartment is using the PLANE method. This method allows for the most generalized compartment description, the simplest being a cube. These compartments may be defined port or starboard, symetric or non-symetric crossing the centerlines. See Figure 4. This type uses cross-section area integration similar to that used in intact hull with the boundaries of the compartment being defined as follows:

1. Fore and aft bulkheads are restricted to be perpendicular to the baseline and centerline planes.
2. The remaining four sides may be defined by skewed planes, the hull or special offsets.

See Figures 4, 5 and 6.

The cross-sections are formed by the intersection of the planes with a waterplane and a defined offset envelope. The offset envelope is necessary to the PLANE type of compartment - it normally becomes one or more sides used in the boundary of the compartment. For this reason

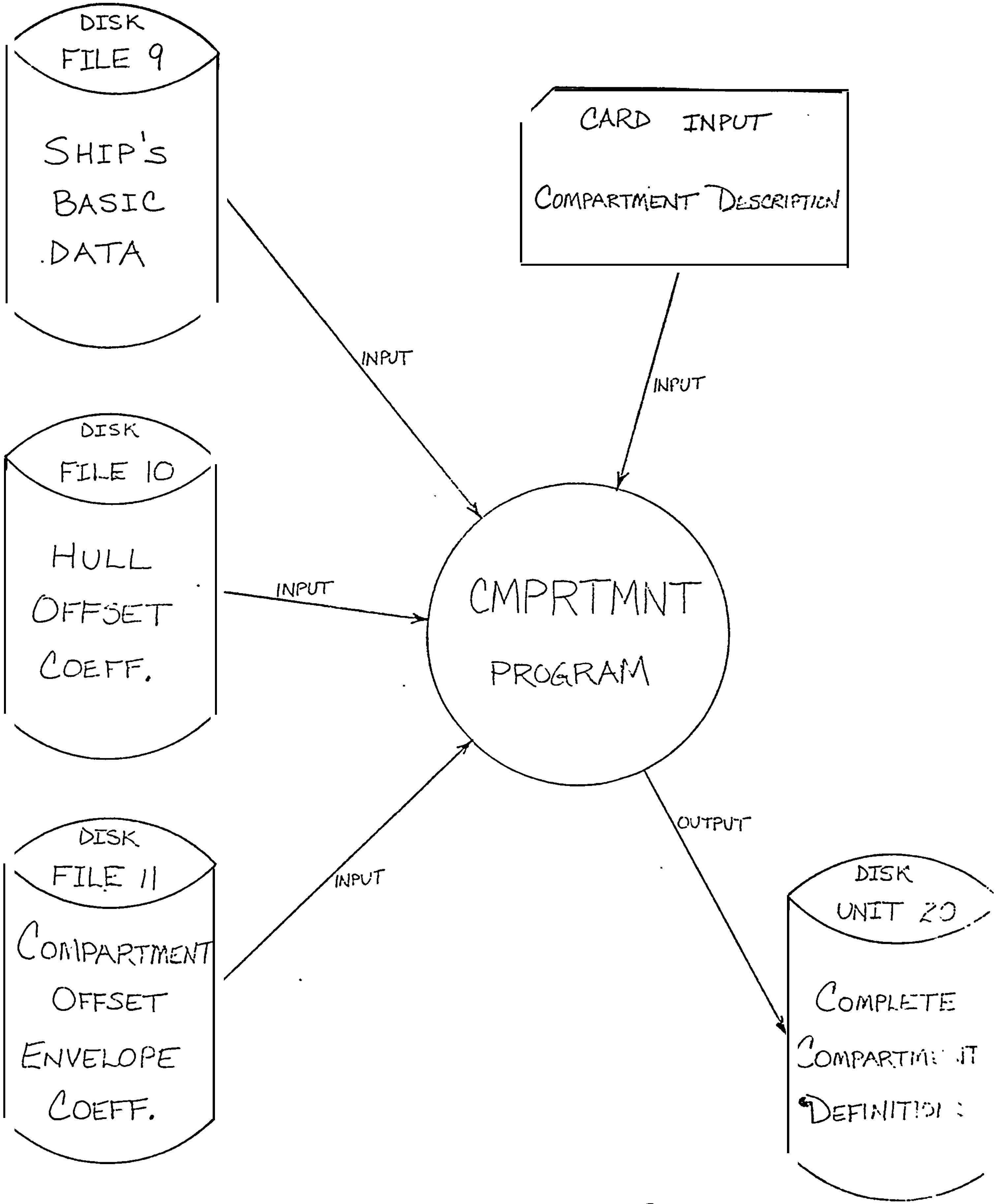


FIGURE 3
CMPRTMNT INPUT AND OUTPUT

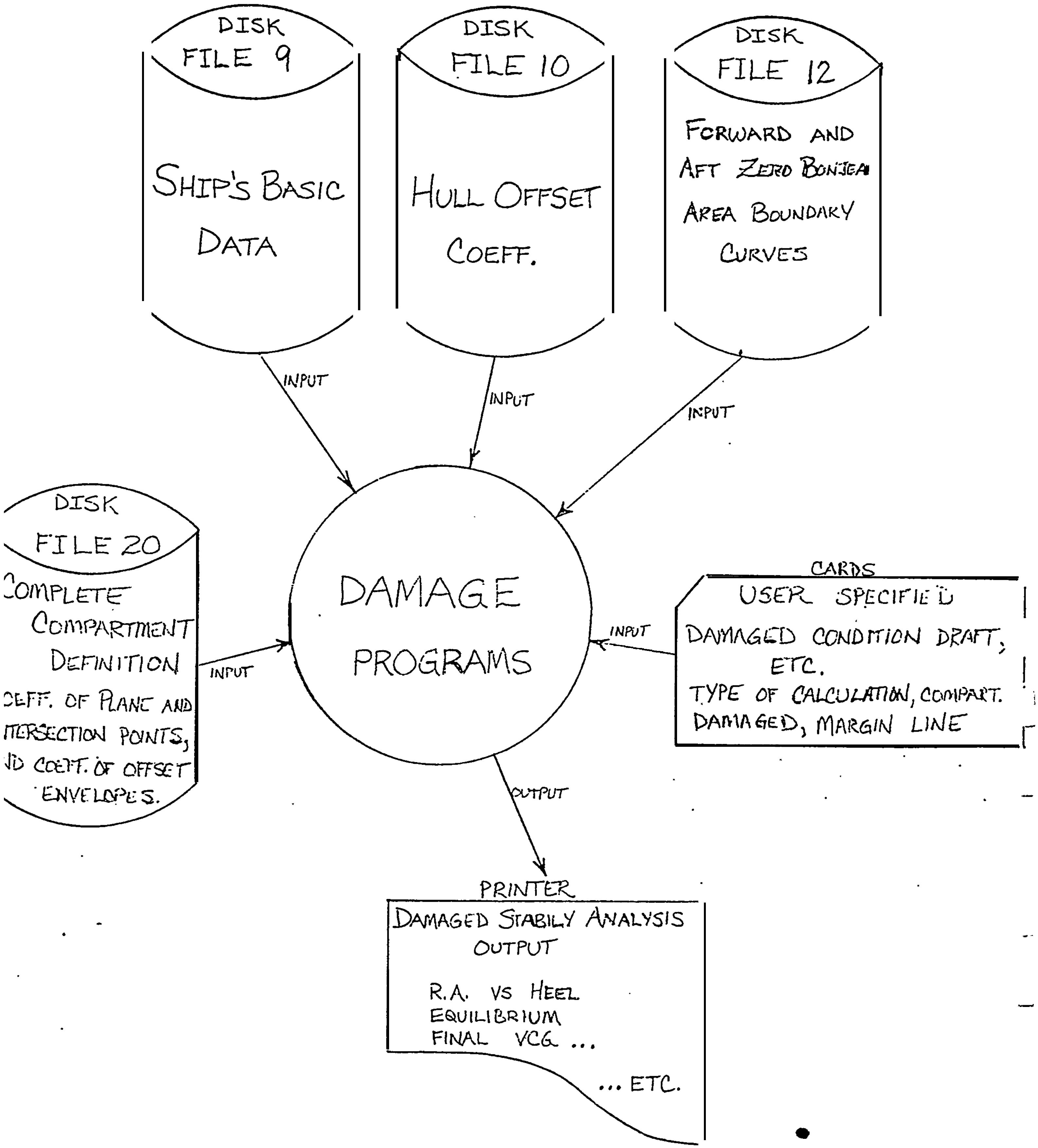


FIGURE 4

DAMAGE-0 AND DAMAGE-1 INPUT AND OUTPUT

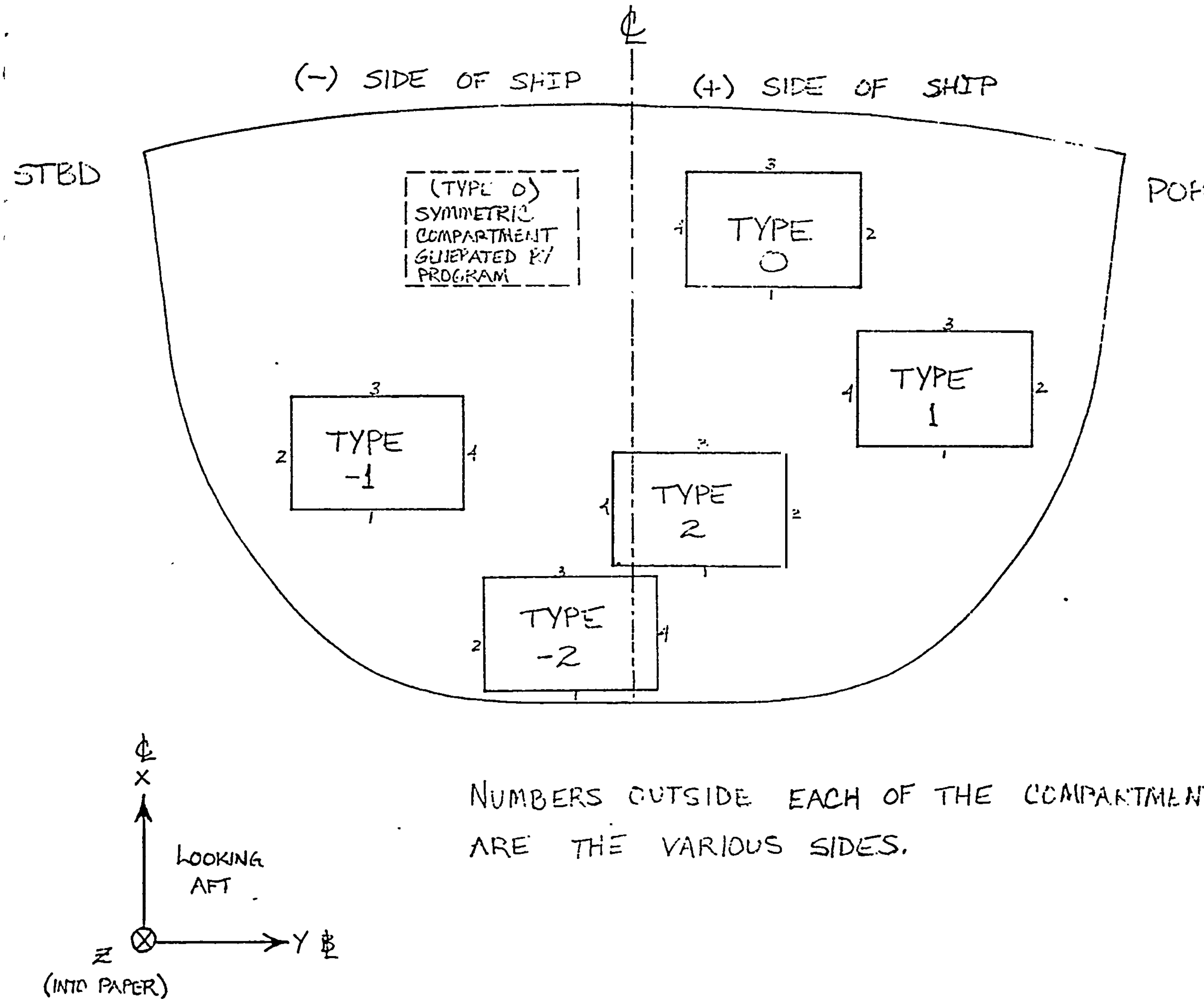
TYPE 0 — COMPARTMENT HAS BEEN DESCRIBED ON PORT SIDE - PROG. WILL GENERATE A SYMMETRIC COMPARTMENT ON STARBOARD SIDE

TYPE 1 — COMPARTMENT COMPLETELY ON PORT SIDE

TYPE -1 — COMPARTMENT COMPLETELY ON STARBOARD SIDE

TYPE 2 — MAJORITY OF COMPARTMENT ON PORT SIDE

TYPE -2 — MAJORITY OF COMPARTMENT ON STARBOARD SIDE



NUMBERS OUTSIDE EACH OF THE COMPARTMENTS ARE THE VARIOUS SIDES.

FIGURE 5
PLANE METHOD COMPARTMENTS

SIDE 1 - LOWER
SIDE 2 - OUTBOARD
SIDE 3 - UPPER
SIDE 4 - INBOARD

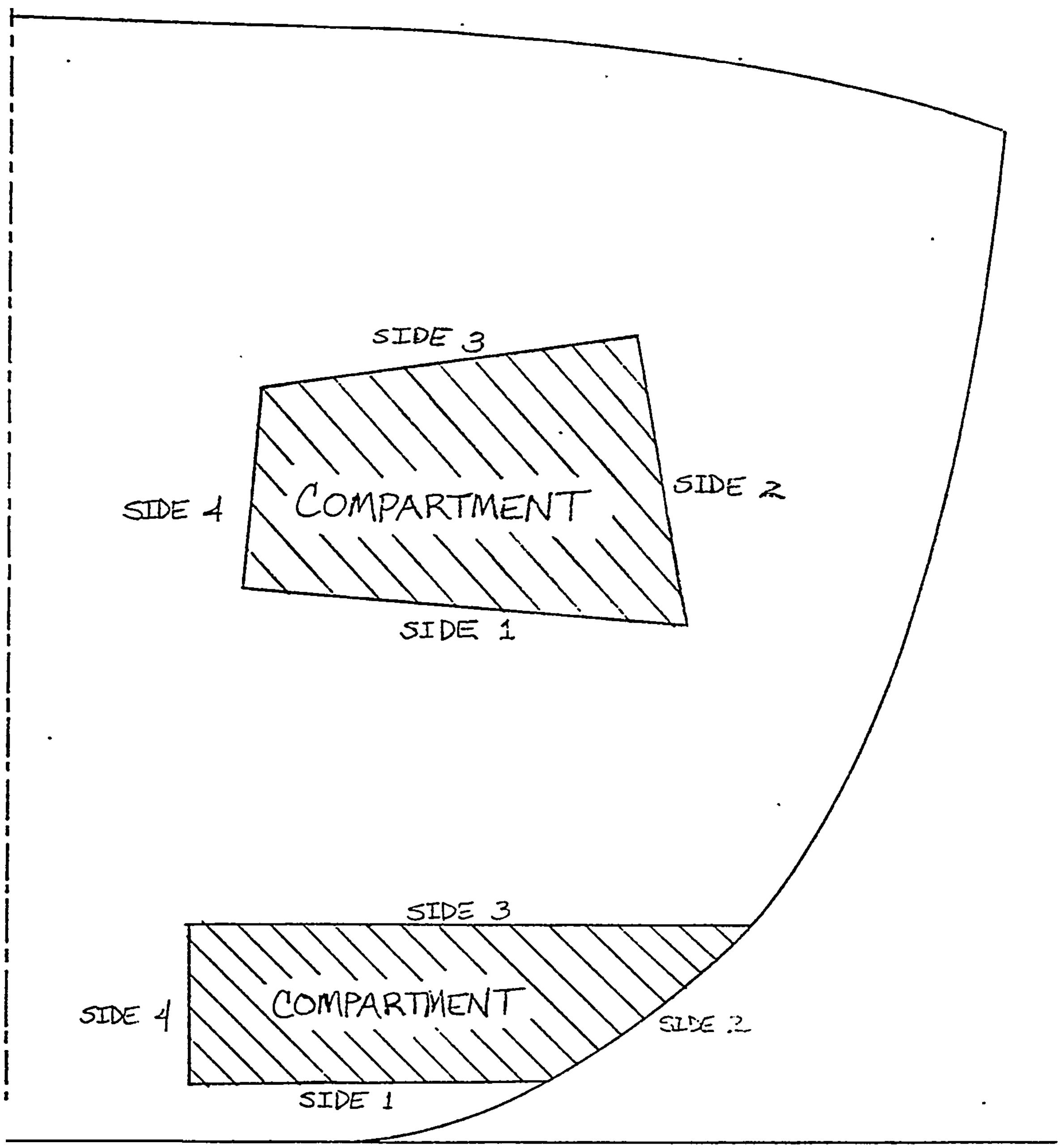


FIGURE 6
NUMBERING OF COMPARTMENT SIDES

the offset envelope is usually a description of a section of the molded hull and is coded in a similar manner. (See Figure 7.)

However, the offset envelope may describe shapes other than that of the molded hull. This would be necessary for a compartment which is unable to be described by any of the types already mentioned. See Figure8,for example.

There is also available the ability to define a flooded compartment by its volume and center. This implies that the compartment is flooded at all times during the analysis. The volume may be entered as negative; this provides the capability to the program for analyzing a run-off problem.

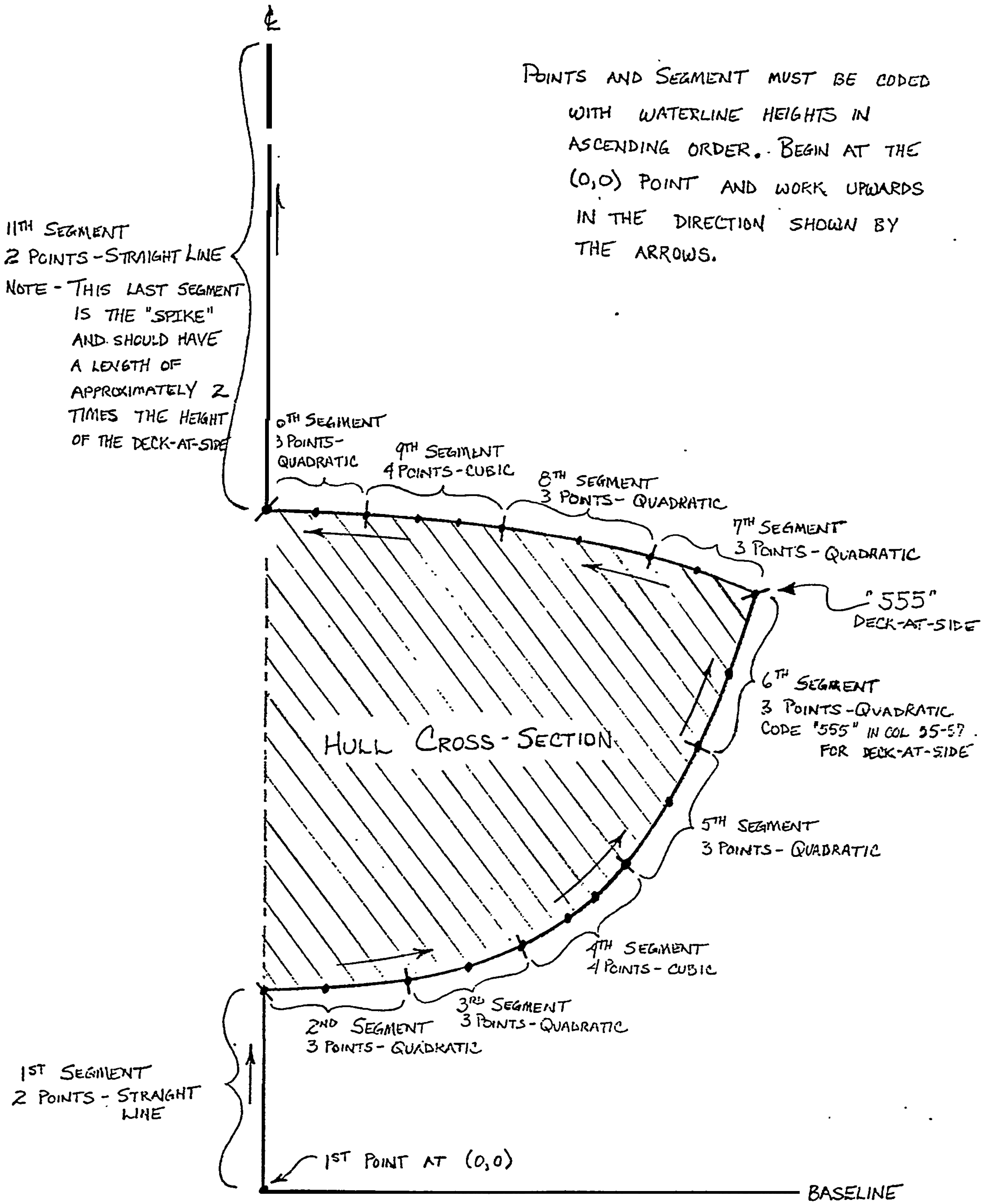
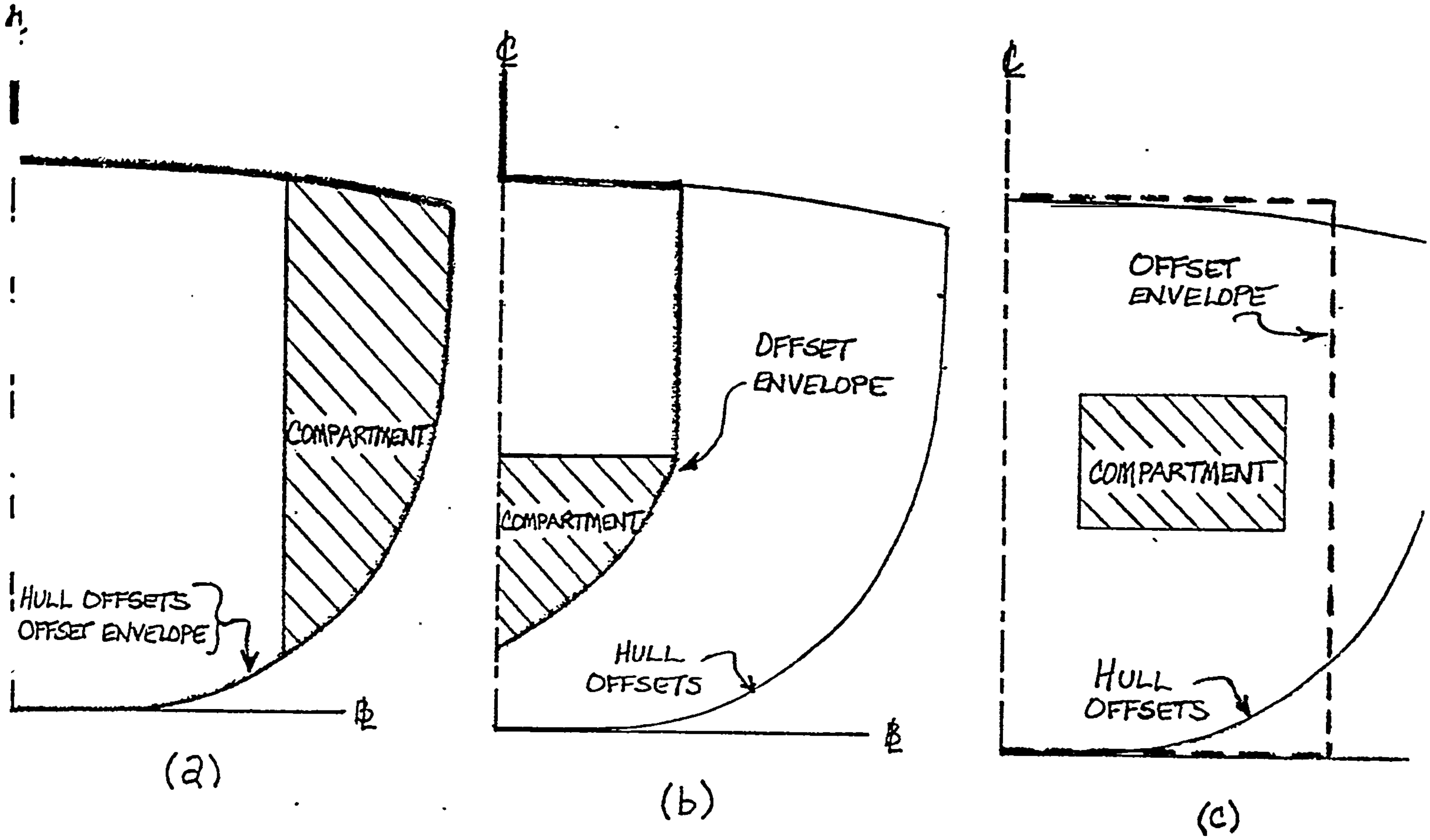


FIGURE 7
SECTION SEGMENT DEFINITION



(a) OFFSET ENVELOPE IS THE SAME AS THE HULL OFFSETS. USED WHEN COMPARTMENT HAS PORTION OF THE HULL AS ITS BOUNDARY.

(b) OFFSET ENVELOPE HAS SAME SHAPE AS PORTION OF THE COMPARTMENT'S BOUNDARY. USED WHEN COMPARTMENT REQUIRES OFFSETS TO DESCRIBE IT.

(c) OFFSET ENVELOPE IS ANY SHAPE. USED WHEN OFFSETS ARE NOT NEEDED TO DESCRIBE THE COMPARTMENT. NOTE: HULL OFFSETS MAY BE USED.

FIGURE 8
USE OF OFFSET ENVELOPES
FOR DEFINING PLANE TYPE COMPARTMENTS

SPADES AS AN AID IN SHIP DESIGN

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At Cali and Associates, Mr. Ulsteen is responsible for data base management, program development and hull technical calculations. He has nine years' experience in development of computer software for ship design and N/C production. Mr. Ulsteen has a B.Sc. degree in Naval Architecture from the University of Strathclyde, Glasgow, Scotland.

INTRODUCTION

The use of computers has made a tremendous impact on the ship design and the ship building processes in recent years. Designers utilize special programs to optimize their design according to economic and performance requirements. for a certain type of vessel in a certain type of service. From this iterative process, the optimum parameters are obtained and the preliminary design carried out .

The ship builders have sophisticated computer software available to them for Numerical Control of cutting machines and machine tools. Thus, the generation of parts and other manufacturing aids through the use of computers has been widely accepted for saving costs and production time, and for increasing the accuracy of the parts.

In order to properly describe a vessel with its complicated form and structural design, numerical hull fairing and structural description programs have been designed and extensively refined. The main objective of these programs is to generate a mathematical description of the hull surfaces and associated structural details with as great an accuracy as is feasible. This description is stored on a permanent data base which is accessible to all the N/C and production related programs within the shipbuilder's computer environment.

But, separating the design analyzing programs and the N/C production programs is a large void, partially filled with miscellaneous ' stand alone' and unrelated programs for the various detail design and engineering tasks to be performed, either by the designer or the builder. These programs have usually been written in order to solve a particular problem, and do not offer an extensive comrnunication link with other programs or systems.

This paper is intended to demonstrate how an existing N/C system, such as the 'SPADES' System, can benefit design and engineering work during the design cycles prior to the production oriented N/C lofting. Because of the system's large data storage capability and the use of a common Data Base for storage and retrieval of all hull geometry and structural related data, such a use will not only benefit engineering through reduced amount of input required at each stage during the design, but will also reduce considerably the amount of work that would otherwise have to be done downstream during the final engineering and lofting process.

HULL FORM DEFINITION AND PRELIMINARY DESIGN CALCULATION

It is assumed that at the beginning of this phase, the naval architect has already established a set of preliminary lines representing his first approximation of the hull form to meet the economic and performance requirements of the ship. He is now ready to start the iterative process between hull forrn and calculations to refine this first approximation.

The numerical FAIRING Program is utilized to define the initial lines of the hull without performing an actual fairing. A discreet number of offset points are selected from the preliminary lines in order to define the boundary control lines and the main design stations. From these data, a number of waterlines or diagonal planes is selected, and the lines generated and stored on the Data Base. The check drawing of these lines and stations is ins petted for reasonable fairness for calculation purposes, and the original offsets changed, if necessary.

A numerical fairing of the lines will normally not be performed at this stage, as detailed definitions and accurate fairness for lofting purposes are not required yet. However, we do have the basis for the final fairing and hull definition already stored for later use.

From these preliminary computer lines, any number of stations and frames can now be interpolated and stored on the Data Base. The usual number of "Simpson" stations and additional frames, if required, are selected for calculation and the Curves of Form calculations carried out by the HULLCAL Program Module. A drawing of the hydrostatic curves, as well as a tabular printout, is provided by the program. By checking and comparing these with the desired properties from the design requirements, it can now be established what changes will have to be made to the original lines in order to satisfy the design requirements.

The necessary changes can be made to the main dimensions of the vessel, the boundary control lines, and the preliminary station offsets that were originally supplied to the FAIRING Program. The new lines and stations are generated and the Curves of Form calculations are repeated. These steps are repeated as necessary until the results are satisfactory within the established design tolerances.

Other design criteria, such as intact stability and floodable length requirements, can also be checked simultaneously or as a next step in the design procedure. Usually, the main watertight decks are described through the HULLOAD Program and stored on the Data Base at this time. The cross curves of stability and floodable lengths can now be computed for the portion of the hull below the specified decks. If the results are not acceptable, the original lines are changed and the steps repeated as before. In the case of floodable lengths, the watertight subdivision bulkheads can be relocated to meet the requirements for compartmentalization.

At some stage during this design cycle, the naval architect might want to verify that the design will meet the performance requirements as far as cargo and tank capacities are concerned, as well as the damage stability requirements. Some additional frames in way of the tanks, cargo compartments and engine room, if necessary, are generated and stored. Through the HULLOAD Program, the main internal decks and bulkheads are described and loaded to the Data Base. Tank and compartment descriptions based on these bulkheads and decks as boundaries are given to the HULLCAL Program, and preliminary capacities are computed.

The same compartment descriptions can be used individually or combined when computing the damage stability for various critic al cases and vessel conditions. Thus, shortcomings in the design relating to capacities or compartment locations can be corrected at an early stage with very little effort. The necessary changes are made, and the same steps are then repeated.

Since the damage stability calculation is available through the system, this should be used as the tool for determining the allowable maximum compartment sizes and bulkhead locations, rather than floodable lengths. This program will calculate not only the sinkage, but also the stability after flooding for all types of operating conditions and damage cases.

As in the preliminary fairing step, we have now established most of the basic definitions and program input instructions that will be required at a later stage when the final calculations are to be performed. Only a few more detailed descriptions might be necessary to add at that time.

When the preliminary design is completed to the satisfaction of all the outlined requirements, the detailed hull definition of all necessary control lines is given to the FAIRING Program. At this time, the actual hull fairing will be performed, taking into account the details required for the lofting process.

All the construction frames, as well as the final design stations, are generated and stored on the Data Base. The major decks and bulkheads are also defined and stored; and at this time, the final Mold Loft Offsets for control lines, waterlines, buttocks, deck and bulkhead traces can be printed. A complete lines plan and a body plan on frames is extracted through the DRAWING Program.

The detail touches, if any, are added to the HULLCAL input instructions, and the final calculations including Bonjean curves are rerun, generating the tabular printouts and corresponding drawings, as required.

Although the type of programs that are utilized in the above demonstration are oriented towards the final lofting and engineering phases of the design and are not intended to be "automatic design programs”, they lend themselves to the naval architect as very useful tools in performing the design iteration. Another advantage of using such a production oriented system during the design is that the majority of the input instructions and definitions are made at an early stage, thus saving lead time and manpower in performing the final design and hull definition.

There are, of course, factors other than mentioned above which affect the finalization of the hull form. However, the introduction by the naval architect of these factors in the design iteration will not reduce the validity of the procedure described above.

STRUCTURAL DESIGN AND SCANTLING DEFINITION

At some stage during the preliminary design, the scantlings of the hull structure must be determined. A typical production oriented N/C system such as the 'SPADES' System is not intended to compute the scantling requirements. While there are a number of special programs available to the designers for various stress and strength analysis, some means are needed to transfer the determined scantlings and structural data to engineering drawings and subsequently working drawings, and to the Data Base for lofting purposes.

In this process, as for the preliminary design cycles, the 'SPADES' System can be a very useful tool for the design engineers. If utilized during this phase of the design, the system will, in the process, create and load the bulk of the data needed in the Data Base during the subsequent lofting and production phases of the shipbuilding process.

The following procedure assumes a longitudinally framed vessel. In the case of a transversely framed ship, or a combination of longitudinal and transverse frames, the sequence of the various steps may have to be altered. This sequence is to a certain extent arbitrary and will generally be determined to suit each design and the specific practices of each engineering organization. The main objective, however, will always be the same: store as much of the data as possible in the Data Base, and let the computer do the time-consuming and repetitive work.

As soon as the naval architect has the preliminary computer lines generated, a discreet number of frames are interpolated and stored on the Data Base. Based on the scantling requirements, the HULLOAD Program is used to define and load all shell traces from the midship area and extended toward the bow and stern. Although these can be defined by specific locations, the use of relative spacings such as stiffener spacing and plate widths may be more useful at this stage. Some selected references such as the main deck trace at the shell, the bilge area, or the keel, are used as the basis for the relative trace definitions.

The DRAWING Program is now used to extract a preliminary shell expansion drawing and a body plan of frames with the shell traces, as well as the traces of all decks and bulkheads that have been defined. With these drawings as guidance, the traces are now modified and extended toward the ends to suit structural requirements, plating widths and curvature of the bow and stern sections. The changes are made by redefining and adding to the existing HULLOAD data. This way, the Data Base will always be up to date and new drawings can be extracted

at any time as the design is progressing.

In parallel with the above steps, the traces of stiffeners and seams on decks and longitudinal bulkheads are defined and loaded through the HULLOAD Program. As for shell traces, the definition is started in the midship area. By reviewing the preliminary drawings extracted from the Data Base, the traces are modified and extended towards the ends as best suited to each particular deck and bulkhead and the overall structural configuration.

Through the use of the PARTGEN Program, or the DEMO Program, if available, the image of each entire deck or bulkhead is created and stored on the Data Base as a complete drawing. Thus, by using the "window" capability of the system, or in some cases, the "Part Separation" feature, any portion of each image can be extracted and drawn to the proper scale as needed for the scantling or general arrangement drawings.

The design of transverse bulkheads, deep web frames, and transverse girders is handled in the same manner. By utilizing the data loaded through HULLOAD and additional detailed information, the PARTGEN or DEMO Program creates all necessary scantling drawings for the transverse structures.

At some time during the design state, it is necessary to determine the required plate sizes for the bill of material. As steel mills and warehouses throughout the country need more lead time to fill a particular order, it is important to have a fairly accurate estimate of the steel requirements as early as possible. In the case of complex hull forms, a shell expansion drawing may not be accurate enough for determining the proper plate sizes. For this purpose, a preliminary shell plate development through the PLATDV Program is obtained in the critical areas of the hull. From the results of this program, the best suited plates can be determined, the shell seams or butts relocated, or additional seams defined, if necessary. If this is done at an early stage of the design, there will be no impact on steel delivery or production schedules by last minute changes.

At the most appropriate time during the above process of scantling definition, the HULLCAL Program is used to run the Longitudinal Strength Calculations for the various operating conditions of the vessel. This will point out any weaknesses in the structural design, which can be corrected before the design is completed. By using the N/C computer system as a tool in the structural design phase, the design engineers are less affected by design changes in the lines or

arrangement of bulkheads and decks. As soon as the naval architect has altered the lines or relocated any of the main structures, the already established input definitions for the structural data can be reloaded onto the altered Data Base. Only slight modifications may be necessary, and the new drawings can be extracted almost immediately. This is due mainly to the 'ISPADES' System's use of symbolic names for all structures and associated details. All references are made by these names, or if dimensions are used, they are relative to established structures. Therefore, by building up the Data Base during the designing phase, the amount of work involved in recreating or altering drawings and structural data as the design is altered, is reduced to a very minimum.

DETAIL WORKING DRAWINGS

Within the context of this paper, these drawings can be divided into two basic groups:

A. Detail structural drawings to be used for hull construction.
B. Record and information drawings, such as compartment and access drawings, arrangement drawings, and composite drawings.

Because of the different purposes, and in order to obtain the maximum benefit from the use of 'SPADES' in generating these drawings, the two groups will be treated separately.

It is assumed that the structural definitions from the scantlings have been loaded on the Data Base, as well as detailed information such as standard cut-outs or notches for penetrating stiffeners and longitudinal. The stiffeners' size and characteristics have also been defined and loaded on the Data Base.

A. Structural Drawings

The format of these types of drawings has traditionally been the one most suitable for submittal to the regulatory bodies for structural evaluation. But the format most suitable for construction would be that corresponding to the work units, such as sub-assemblies, assemblies, modules, etc.

This conflicting requirement has been solved in some shipyards by creating another set of drawings or sketches geared to work units. This solution, besides increasing the drafting man-hours, has also the problem of maintaining two duplicate sets of drawings. The procedure suggested herein should satisfy both requirements with one set of drawings.

The majority of drawings in this group deals With flat surfaces, such as bulkheads, platforms, flats, floors, girders, etc. All these drawings must be generated as if the structure, regardless of the size, were a single part to be processed in the N/C cutting machine. Then, through the use of the part separation procedure in the PARTGEN Program, smaller parts can easily be extracted.

These drawings relating to non-flat surfaces, such as a deck with sheer and/or camber, will be generated following the same procedure. But they will not be utilized ultimately to extract the actual parts to be cut.

The following sequence of steps covers the case of generating the drawings necessary for a flat deck with or without sheer. The same procedure with slight variations would be applicable to any other ship's structure.

By utilizing the Data Base with its information about the deck geometry and structural details, a "part" comprising the entire deck is generated through the PARTGEN Program. Using the part separation feature, the deck is then divided into the various portions associated with each work unit. As many illustrative details as needed are also generated during this step. Each portion and details are plotted in separate sheets. The welding details, lettering and general notes are finished by hand. These sheets are issued as a multiple sheets drawing for submittal to the regulatory bodies and the owner.

When this process is repeated for other drawings, the various sheets from each drawing can be used to make up a muitiple sheets drawing with all the information necessary to build a work unit. With the existence of these individual structures within each work unit already defined and stored on the Data Base as "parts”, the Mold Loft can now, through the use of the part separation feature, further divide each portion of each structure into the actual pieces needed for nesting and N/C cutting.

B. Record and Information Drawings

These types of drawings will not be utilized by the Mold Loft to obtain parts for construction. They can therefore be generated by taking into account only the engineering needs.

As for the structural drawings, "master" drawings of large areas in the ship are generated from the existing Data Base information through the PARTGEN Program. These drawings are stored on the Data Base, covering each entire deck. They will generally include all boundaries, bulkhead traces, stiffener layout, and cross-section, and all access openings.

Through the use of the "window" capability of the system, or the part separation feature, any portion of any drawing can be extracted in the desired scale. These drawing portions are used by the various Engineering groups for different applications. In the process of extracting the desired portions, additional details pertaining to the intended purpose of the drawings can be added.

It is implied by the use of the above procedures that the Engineering Department assumes full control and respossibility for the loading and maintenance of the 'SPADES' Data Base as far as the structural data and details are concerned. This assures the integrity and compatibility of all the data applicable to the structural design of the vessel. All parties involved can then utilize the Data Base fully for what its name implies: the common source for all hull and structural related data.

The initial task of generating a drawing, whether scantling or detail, is done in an iterative mode. The data on the Data Base is altered or more data added, and to a certain extent, the coding is modified and a new drawing is plotted on the N/C drafting machine. These steps are repeated until the desired result is obtained. At that point, the drawing is finished by hand, adding any necessary details and lettering. When the final drawings have been issued, it will generally be more economical to handle the revision activity by conventional methods. It is, however, of the utmost importance that the Data Base is changed accordingly whenever a revision is made. A manually revised drawing will not have the direct reflection of the Data Base information as a validation feature. But issue of the revised drawing must imply that the Data Base has been revised accordingly if the above procedure is used.

CONCLUSION

Although the 'SPADES' System is basically production oriented towards hull form definition, calculations, structural data, N/C part generation and flame cutting, it has been shown how it can be a very useful tool for the naval architect and the structural engineer during the design phases. The various tasks of the design and engineering procedures can be performed simultaneously, with a few exceptions, with very little additional work and loss of time due to changes and additions to the basic design.

The main reason for this is, of course, the extensive use of the common Data Base by all programs. By building up and maintaining as comprehensive a Data Base as possible, the amount of input data, and thus, the work involved in preparing each computer run, is greatly reduced. In most cases, a program may be re-executed with the changes or additional data included automatically without having to alter the original input data. As the design is progressing, the' latest information will always be available to everyone involved as soon as it has been defined through the system.

With the benefits the designers and engineers can obtain from the use of the N/C system, the man-hours and the lead time required to complete the design will be reduced. But the most important item is the fact that the "mathematical Ship" as defined on the Data Base is as complete as possible prior to starting the actual lofting and N/C production process. This reduces considerably the amount of work and time involved in the lofting process, as well as the possibilities of difficulties or errors in the design or the lofting during the production phase. Any possible errors or shortcomings will have been discovered and corrected at a much earlier stage. To a certain extent, the Data Base can be compared to a prototype of the vessel, not unlike the full size mock-ups and prototypes used in the aircraft and automobile industries.

The following pages show some examples of the type of drawings obtained from the 'SPADES' System during a Hull Form and Preliminary Design procedure. These are intended strictly as examples and do not reflect any attempt to perform an actual design.

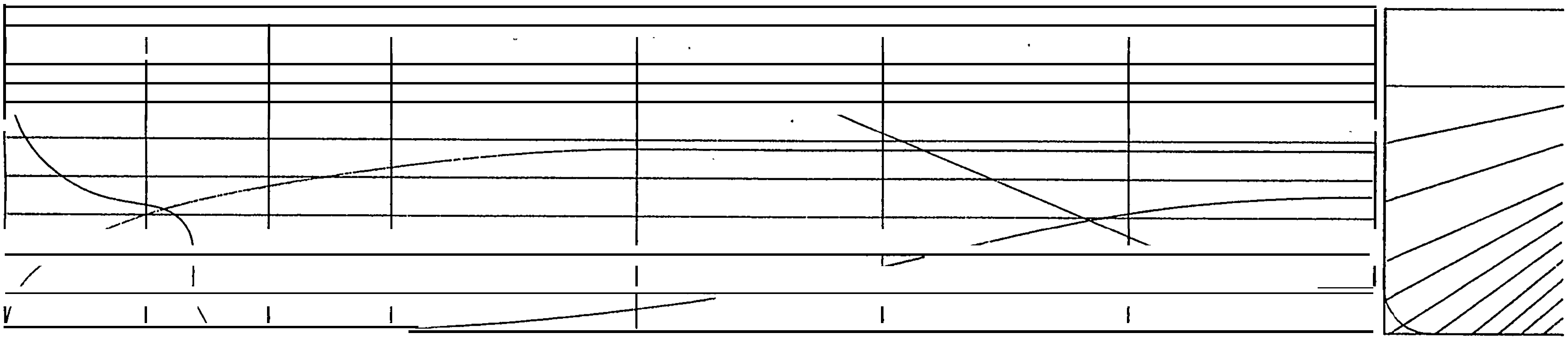
The vessel in the examples is based on the Mariner class design as published in the "Principles of Naval Architecture".

A. Hull Definition

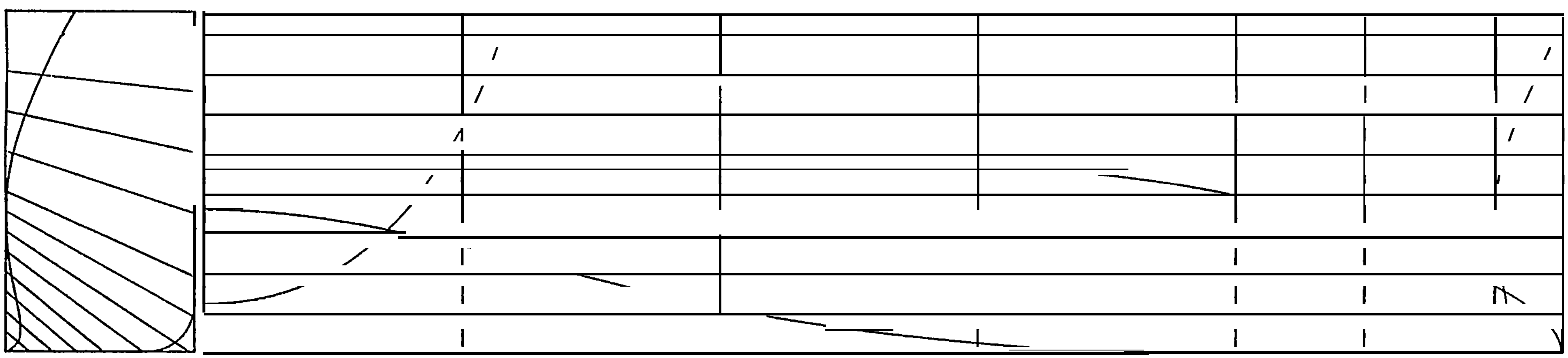
Based on the published set of offsets, the required control lines were defined and loaded through the FAIRING Program. This produced the drawings shown in Figure 1 for the 528 Ft. LBP Vessel. The control lines consist of stem and stern profiles, bottom and side tangents, upper waterlines for forward and aft body, midship station, and station No. **0** (F. P.) for the tangent of the forward waterline endings. The offsets were not faired, and in areas lacking definitions, estimated values were used.

The given basic station offsets were used to define the actual hull form. The set of fairing lines for a discrete number of pre-selected diagonal planes was then produced by the program, as shown in Figure 2. Again, no fairing was performed, only curve fitting and interpolation. The lack of definition of the stern profile is obvious by the shape of the produced lines towards the stern. But this is sufficient for a first approximation of the design calculations.

For calculation purposes, the basic 20 Simpsons Stations were selected, including half stations forward and aft. These were interpolated from the fairing lines and control lines, and the result from the FAIRING Program is shown in Figure 3 for the 528 Ft. LBP Vessel.



TAPE NO. 1560012 - 0 RUN 2AFT CLNS



TAPE NO. 1560002 - 0 RUN 4FWD CLNS

Fig. 1 Control Lines

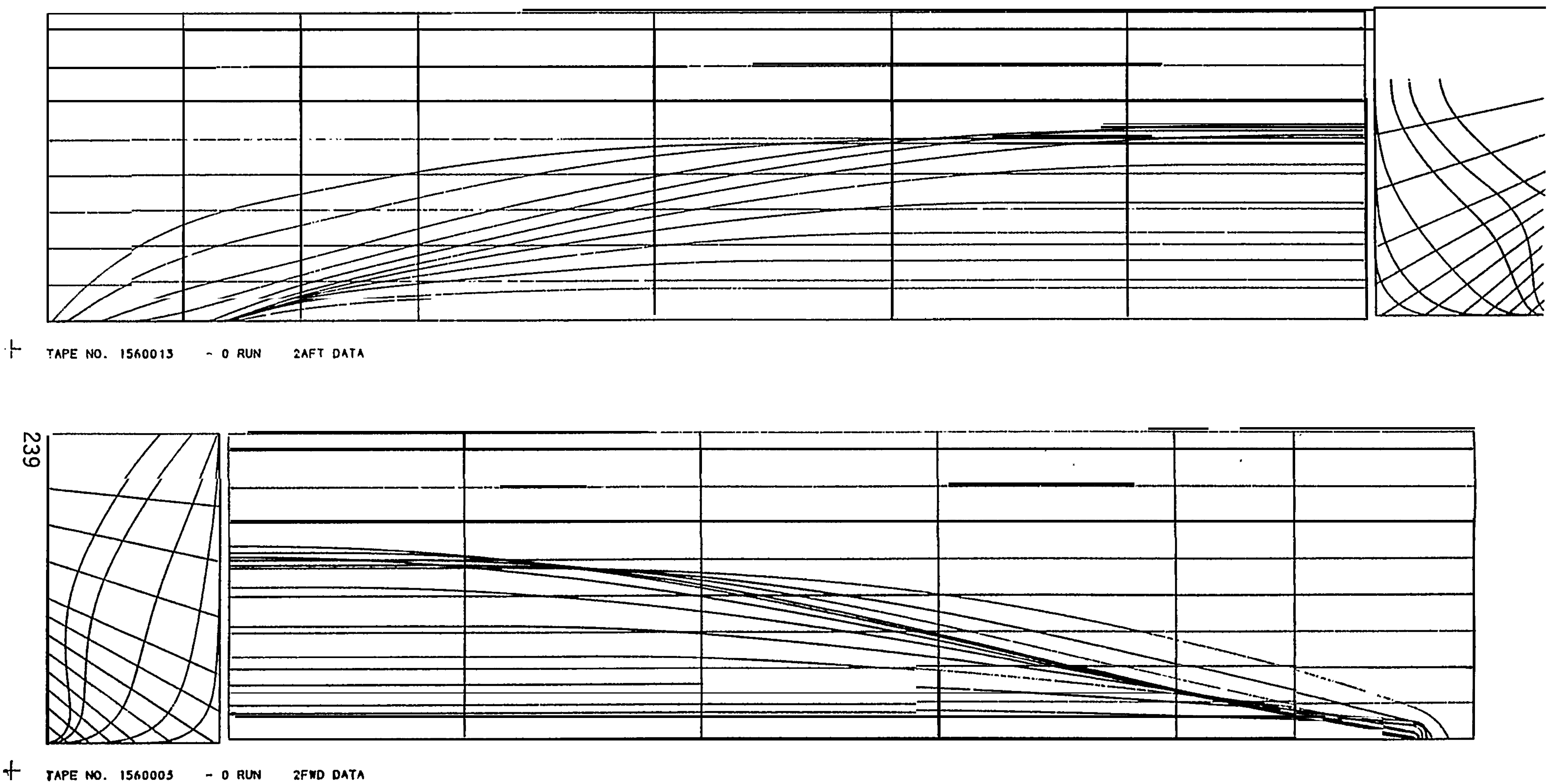
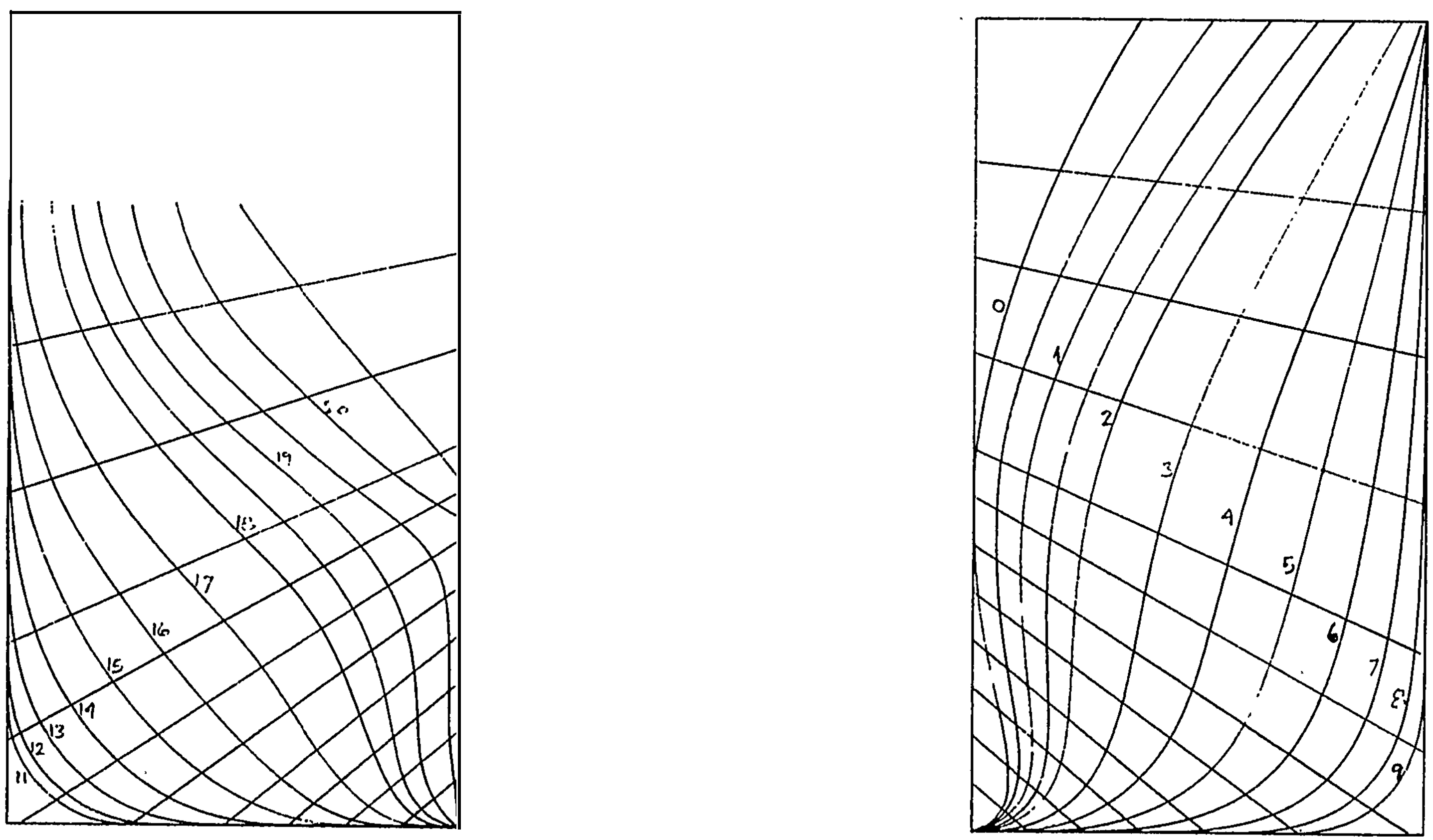


Fig. 2 Fairing Lines



TAPE NO. 1560015 - 0 RUN 1AFT FRAM

TAPE NO. 560005 - 0 RUN 1FWD FRAM

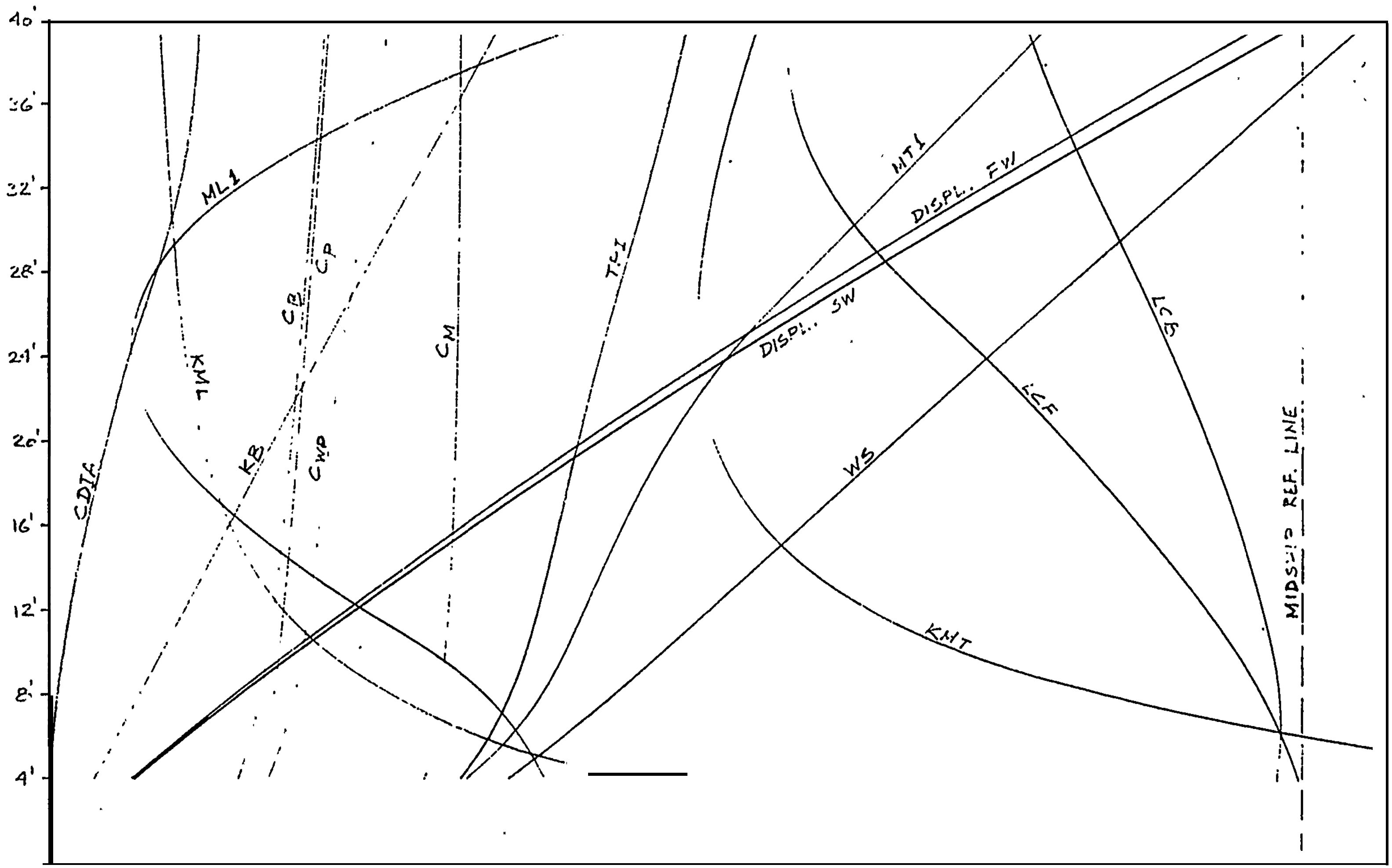
Fig. 3 Stations, Run 1

B. Design Calculations

By using the Simpson integration rule through the HULLCAL Program, the set of Curves of Form shown in Figure 4 was obtained. The calculation was per - formed for the molded lines only, using the previously generated stations and waterlines four feet apart. No allowance for appendages, such as rudder, propeller, etc. , nor shell plate thickness was included at this time.

The corresponding Cross Curves of Stability are shown in Figure 5. These were based on a reference VCG of O feet and calculated for the portion of the hull below the main deck only. The main deck was loaded through the HULLOAD Program. A set of Bonjean curves was also generated and drawn by the HULL-CAL Program, as shown in Figure 6. Every other station was used in order to clarify the drawing.

Finally, a set of floodable length curves was calculated and plotted against the profile of the vessel, as shown in Figure 7. These were based on a margin line three inches below the main deck, and a subdivision draft of 29'10".



TAPE NO. 590001 - 2 06/03/77 FORM

Fig 4 Curves of Form, Run 1

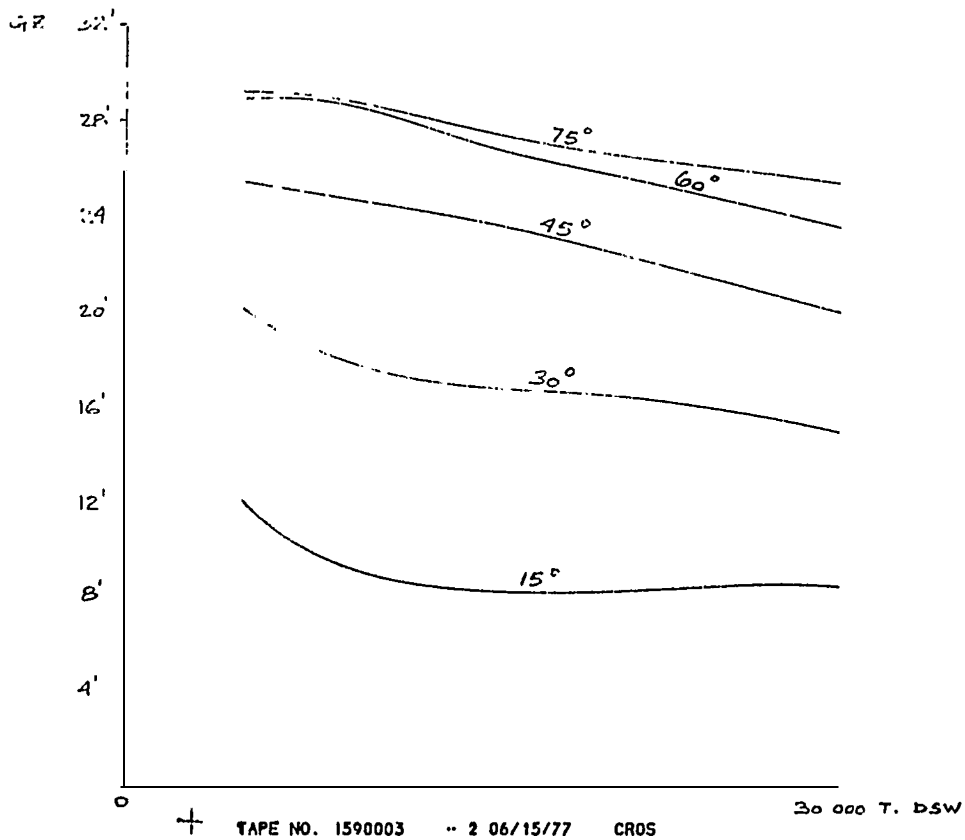
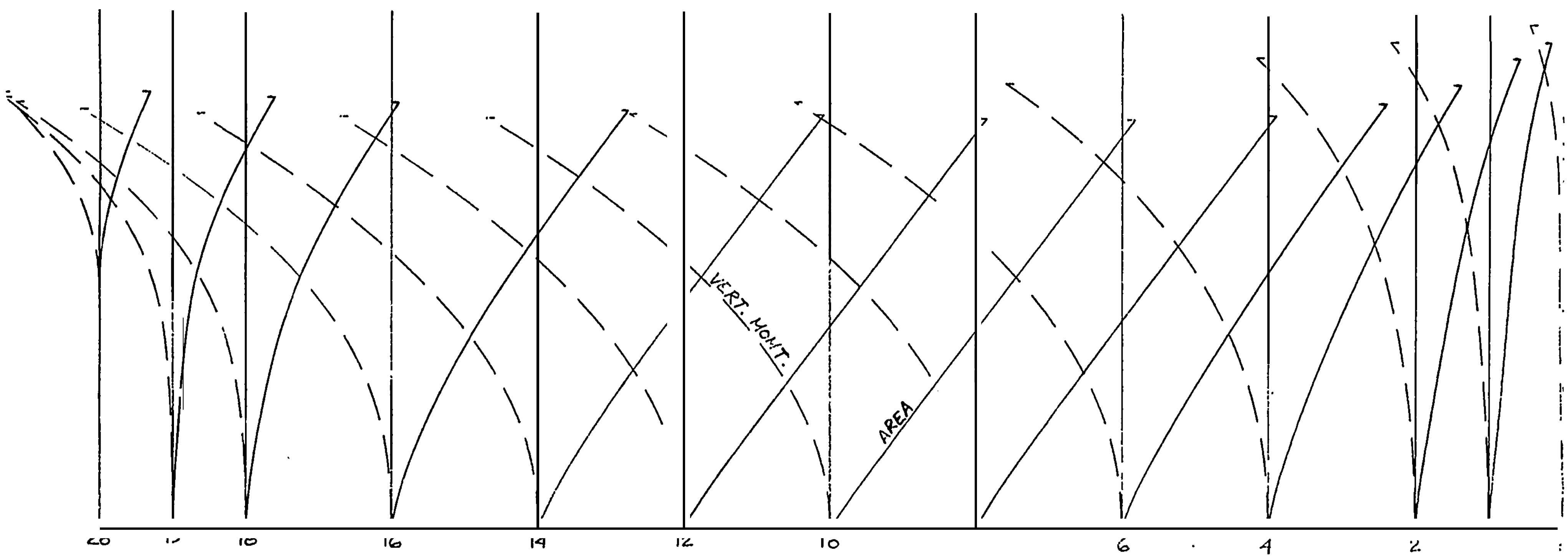
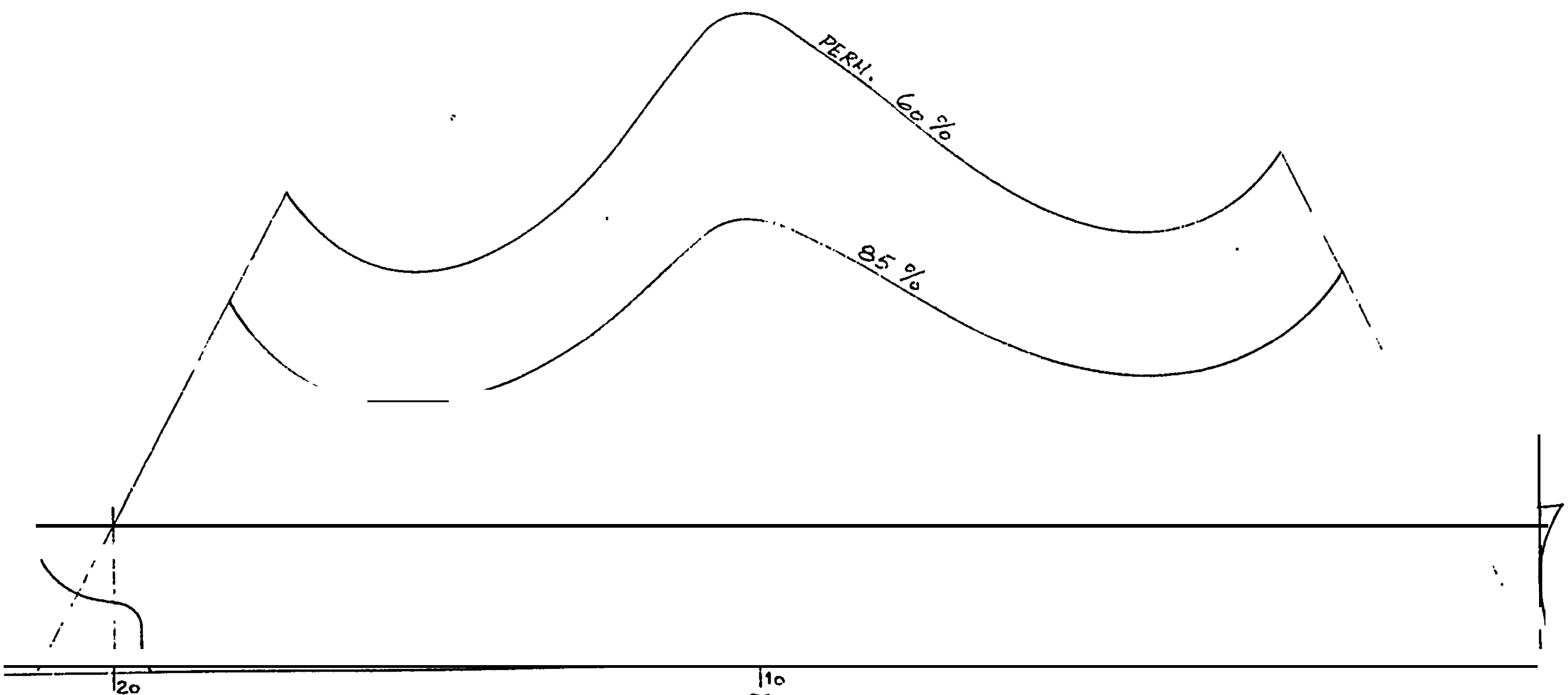


Fig. 5 Cross Curves of Stability, Run 1



TAPE NO. 590002 - 1 06/13/77 BONJ

Fig. 6 Bonjean Curves, Run 1



TAPE NO. 1560134 - 0 RUN 1AFT ELEV

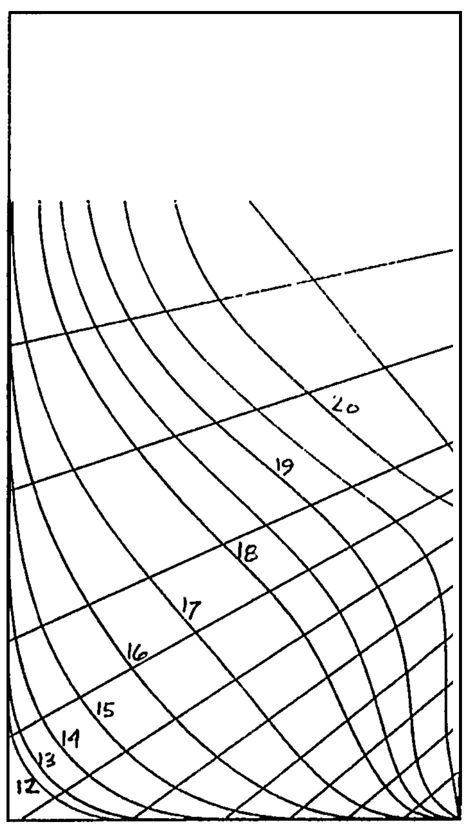
Fig. 7 Floodable Length Curves, Run 1

C. Design Alteration

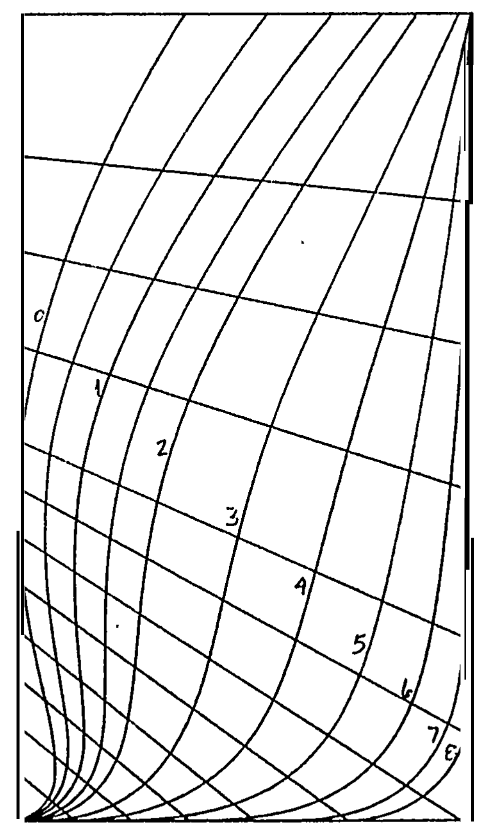
It was now decided to add an 80 ft. section of parallel middle body to the vessel to increase the length to 608 ft. LBP. All other offsets were to remain the same. The "jumboizing" was accomplished by adding 80 ft. to all longitudinal (Z) coordinates of the aft body control lines and given basic stations. The resulting fairing lines did not change, except for their relative location. The Simpson station spacing was increased, of course, and the results of the new station interpolation are shown in Figure 8. Stations 9 through 11 became identical now to the midship station.

The new Curves of Form drawing is shown in Figure 9 and the corresponding Cross Curves of Stability in Figure 10.

As can be expected, these new curves have the same general characteristics as before, except for a considerable increase in displacement. The stability increased slightly, while the largest increase can be seen in the Moment to Trim 1 inch (MT 1).

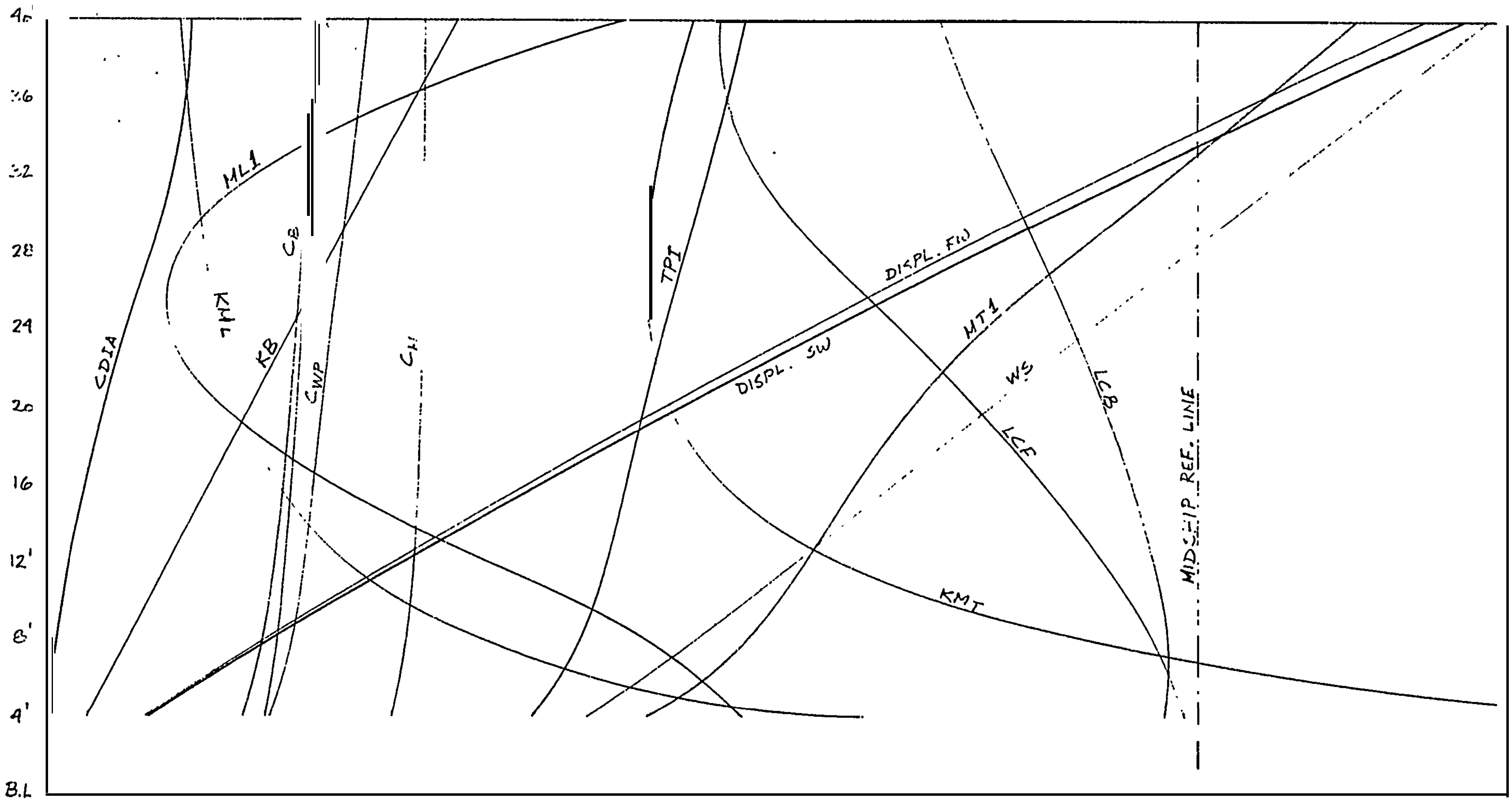


TAPE NO. 1560015 - 0 RUN 2AFT FRAM



TAPE NO. 1560005 - 0 RUN 2FWD FRAM

Fig. 8 Stations, Run 2



TAPE NO. 1590001 - 2 06/16/77 FORM

Fig. 9 Curves of Form, Run 2

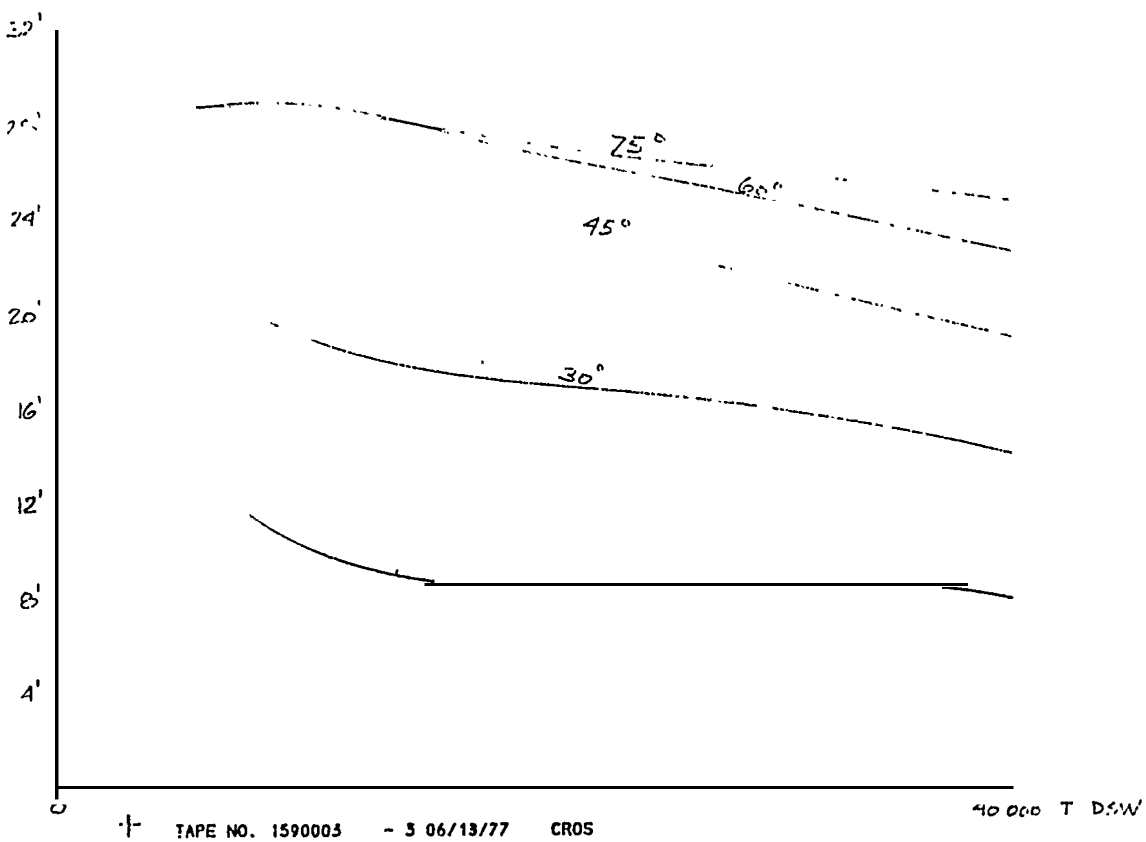
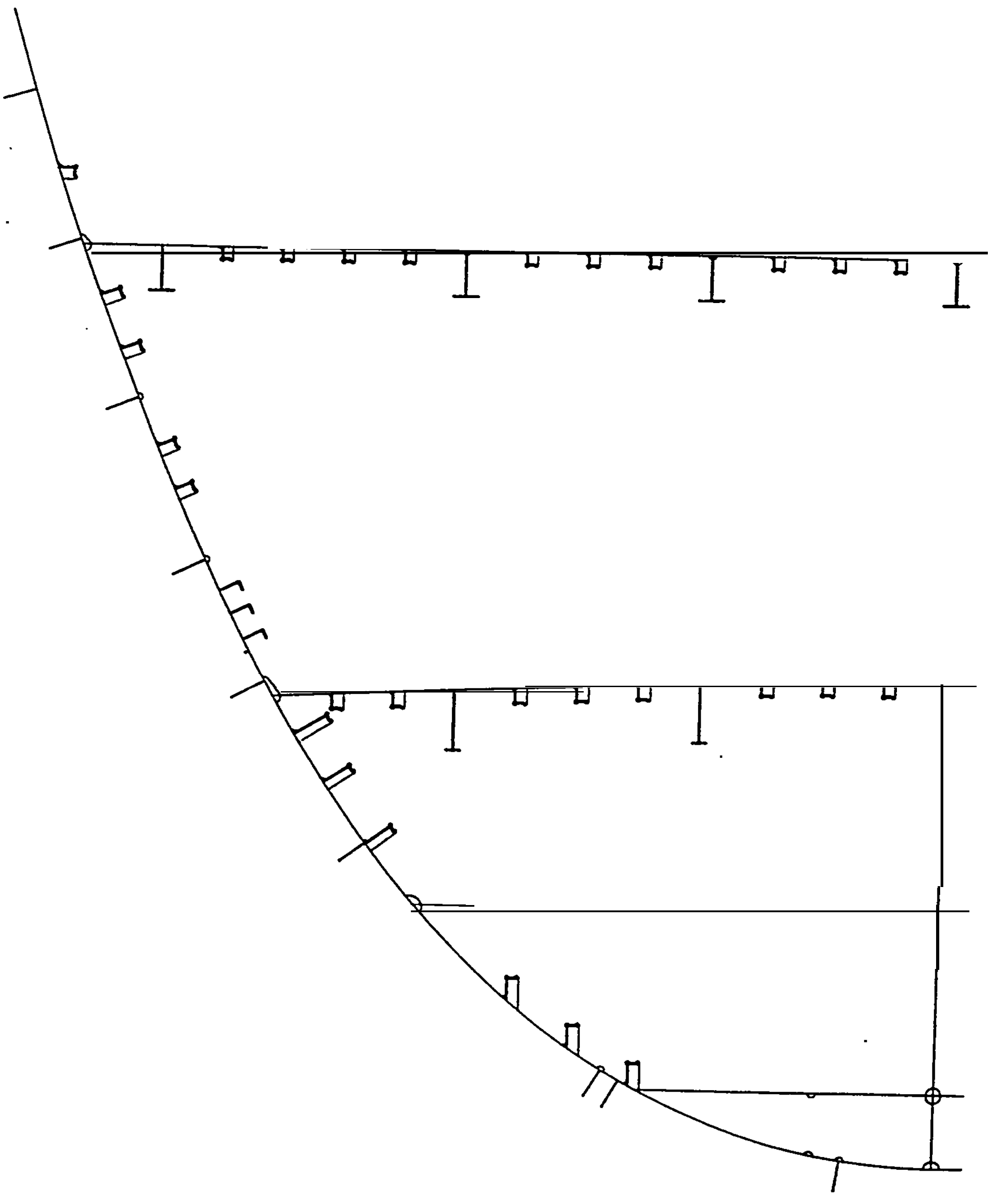


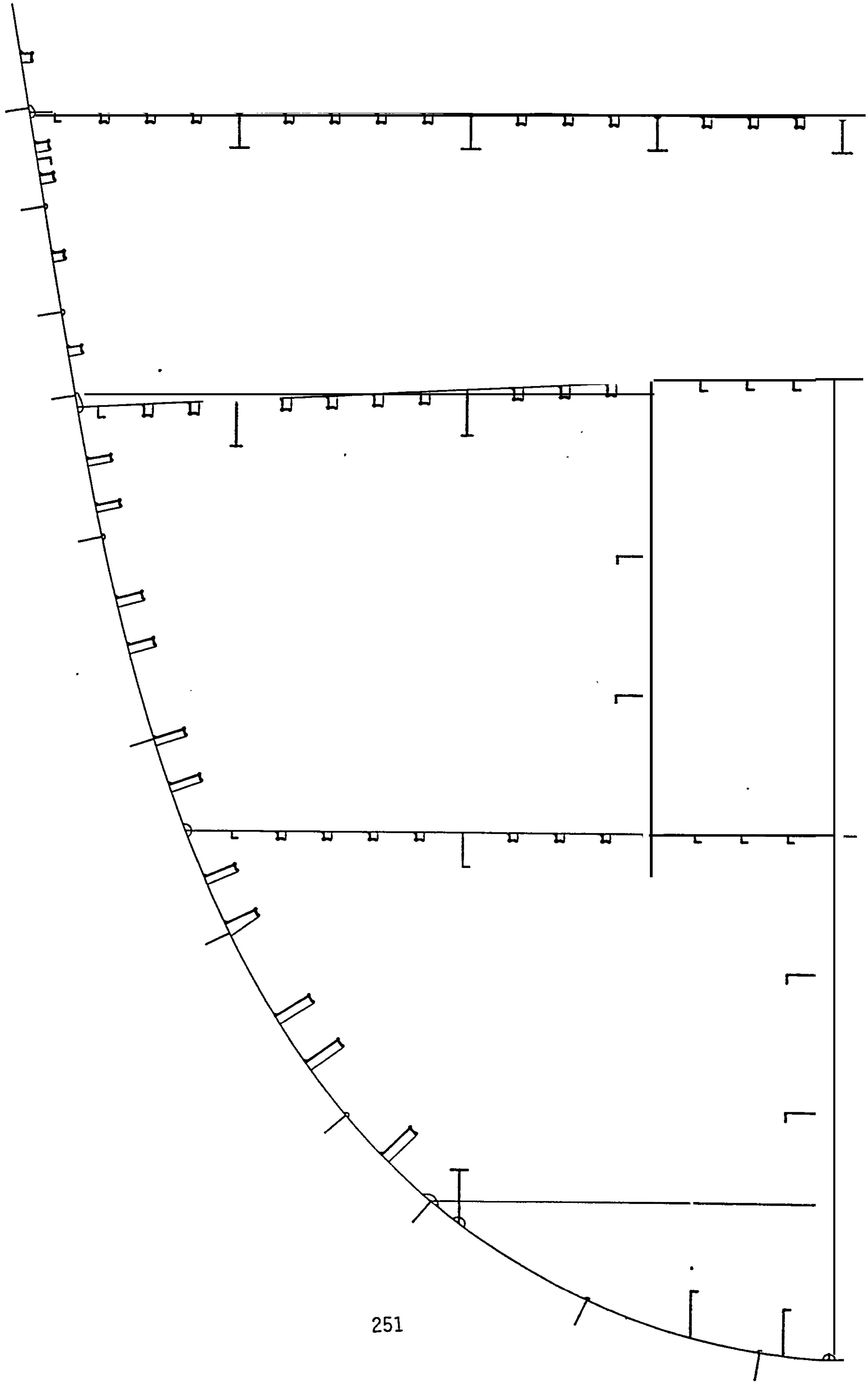
Fig. 10 Cross Curves of Stability, Run 2

D. Structural Design

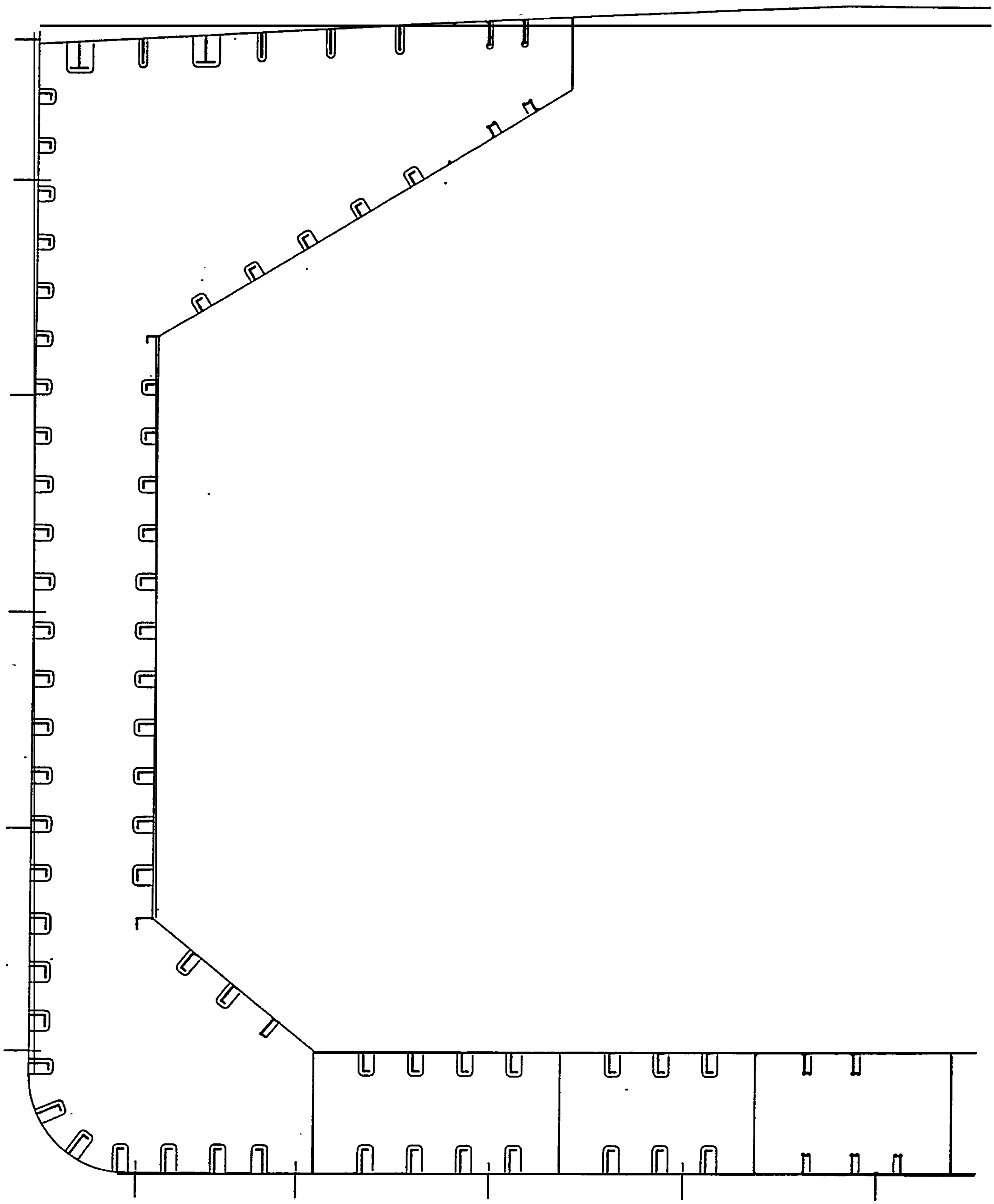
The following figures are included to demonstrate some typical drawings generated by the DEMO Program. These are the basis for the structural drawings of various transverse bulkheads and deep webframes for a large bulk barge. The drawings were generated after the definition of decks and longitudinal bulkheads, longitudinal stiffeners and girders, shell seams and detailed cut-outs and notches were defined and loaded on the Data Base.



93000 - 7



E NO. 932001 - 4



TAPE NO. 93002 - 4

PRESENT AND FUTURE AUTOKON

Jan F. Mack
Aker Engineering A/S
Oslo, Norway

Currently, Mr. Mack is Project Leader at Aker Engineering for Interactive Steel Design, a joint project with Shipping Research Services and the Central Institute for Industrial Research. His responsibilities include the user interface with the system and logical database design. He has spent about two years in the development of the AUTOKON/ALKON norm system for ships and semisubmersibles.

Mr. Mack has a B.Sc. degree in Naval Architecture from the University of Newcastle upon Tyne, England.

1. INTRODUCTION

The total design and production of a new product is particularly a problem for large projects, for example special purpose ships and offshore structures, where a close co-operation and control is demanded by owners, classification societies and officials in general.

In today's situation, lacking as it is in new orders, the builder is often forced by the terms of the contract to spend only a very short period of time on design activities. Shortening the leadtime for design and work preparation is as very important for the ability of a company to compete. Preferably this shortening of lead-time must not induce extra costs or be at the expense of prduct quality.

Based on our experiences in the use of EDP as well as our plans for further development,we will focus on what has been done and what may still be done to strengthen our competitiveness in this area.

2. HISTORY

The Aker Group was a pioneer in the practical use of numerical control systems in production, and the use of EDP for efficiently producing information for numerical control.

At the end of the 50s the Central Institute for Industrial Research (CIIR) developed a numerical control unit for oxygencutters and drawingmachines. This control system was called ESSI and was connected to an optically directed oxygencutter at Stord Yard.

In 1961 this system was used for production tasks in the yard. In the first period the individual plates were coded manually on to papertape. At a very early stage Kongsberg started producing this control unit, and has since delivered units for drawingmachines to a large number of companies within shipbuilding, aircraft industry, car industry, textiles, electronics and cartography.

To obtain an efficient numerical description of complicated geometry and subsequent generation of papertape, CIIR, SRS*and AG started a co-operation in 1961 (later called the SIAG co-operation). The purpose was to develop an EDP system. This system, eventely named Autokon, was used in production as early as 1963. Thus the Aker Group was the first company in the world to use such a system for production of ships.

This system has later been expanded. and improved. In 1976 it consisted of a suit of batch application programs for a variety of products covering different aspects from early design through production.

Approx. 50-60 yards in Europe and the US are using the system today.

3. AUTOKON 76

AUTOKON has automated some of the previous time consuming jobs like hull fairing and shell plate development. But apart from generating information, AUTOKON provides tools for storage and retrieval of information and possibilities for manipulation of information for a variety of purposes. AUTOKON enables the user to describe in great detail the entire steel structure of a vessel or structure in the database, and to extract a variety of design and production data.

* Shipping Research Services

It is in other words a "drawing generator", but also produces N/C-information, material lists, weight calculations etc.

The main functions of AUTOKON are:

- Formulation of design, drawing and production procedures.
- Structuring of data which are added to the system. Taking care of necessary identification systems.
- Definition of plane geometry.
- Fairing of curves.
- Expansion and verification of complicated geometry.
- Detailing of complicated structures.
- Standardisation of structure elements.
- Material specifications as input to programs for material ordering.
- Control of automatic drawing equipment.
- Numerical control of production equipment like automatic cutting machines, bending machines etc.
- Supplying of data for mounting and assembling such as measurements, weights, centers of gravity, production time etc.

The way of building up master geometry and structural information in AUTOKON is very analogous to the "manual way". First the basic "external" surfaces like shell and upper deck are defined, thereafter in sequence the "internal" basic surface such a longitudinal and transverse bulkheads, tank tops and tween decks, transverse and longitudinal web frames and stringers, etc. See fig. 1.

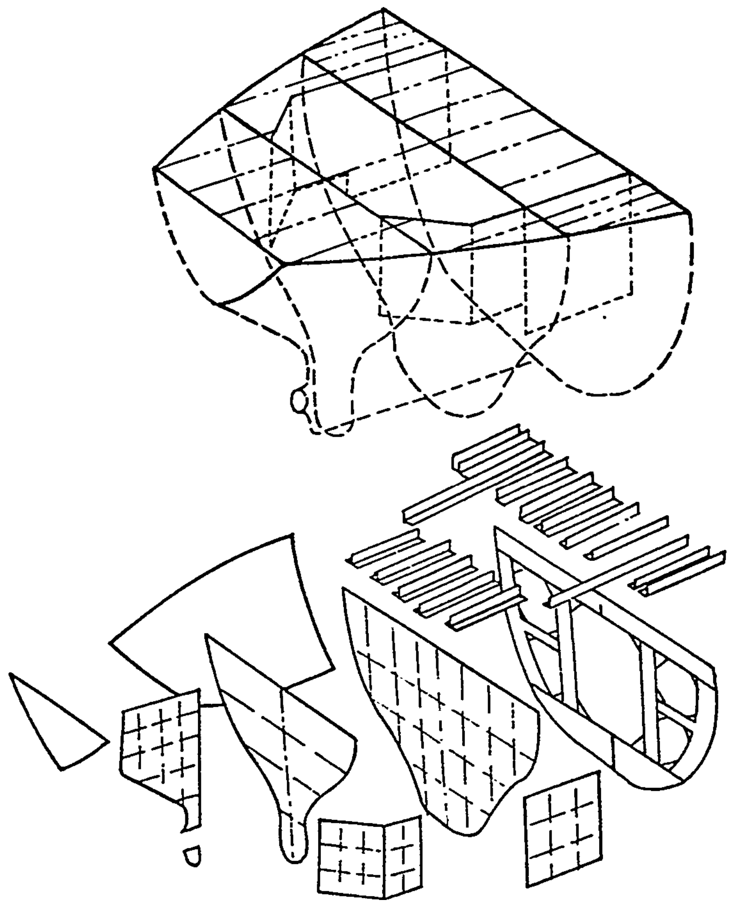


Fig. 1 : Design surfaces and details.

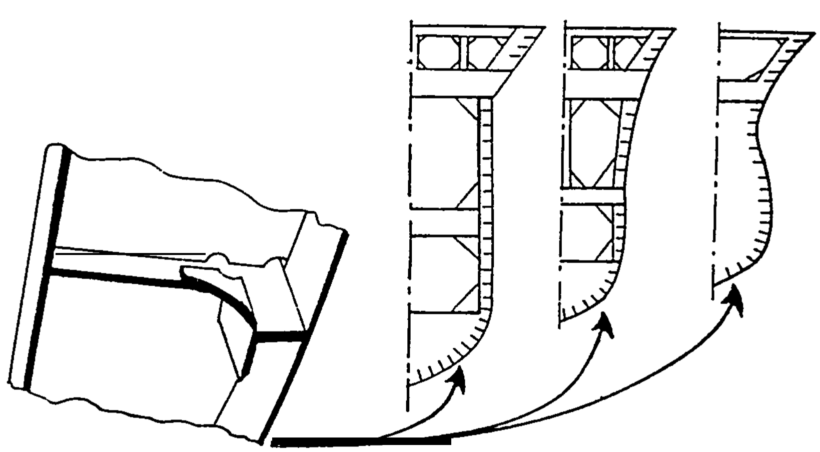


Fig. 2 : Repetitive local stiffening.

On these various basic surfaces the main stiffening is defined, thereafter, the local stiffening. It is not a question of defining piece by piece all information, say 100 local stiffeners on a web frame with a bracket connection to the longitudinal frame, see fig. 2. By means of norms, all stiffener information is generated by a short statement. This statement gives the name(s) of the standard details as well as the environment, for example a set of longitudinals and a web frame. The resulting definition includes the actual shape of the brackets which may all be different due to changes in the angle of run of the longitudinal. The same technique applies to adding cut-outs and holes.

If there is a series of adjacent web frames of similar type, but with different hull form contours, another norm statement will cause the stiffener norm to include all these webframes (fig. 2).

The effect of using this data technology is to reduce the man-hours as much as possible throughout the design and production process, and at the same time improve the consistency of information. Other consequences of using the system are:

- Greater accuracy in design and production.

- Less possibility for errors.

- Reduced routine work.

- Important detailed information available early in the design process.

- More accurate specifications for material ordering.

- Much better control and communication of data between different but mutually dependent departments and yards. (The computer terminals communications with a common data base).

.1 The norms

The basis of the present system of norms rests with ALKON, a problem oriented computer language. It is necessary to know some of the basic properties of this language in order to understand the norm system:

- It maintains a dialogue with the AUTOKON database.

- It has very extensive features for describing geometry.

- It is general in nature and may be used to store various types of information on the database.

  Various data structures may be defined by the user.

- An ALKON manuscript may be stored temporarily (REP) **or** permanently (NORM) on the database.

The last mentioned property is the key feature which enables advanced commands to be built up in the ALKON language. Commands are called NORMS.

It is noteworthy that the simplicity of ALKON and the norms enables the engineers to design and implement systems dealing with problems like:

- Structuring of data.

  Definitions of macros at various levels including also the library of standard details.

  Doing general data manipulation, particularly the various output functions.

This system of norms has been built according to a modular and hierarchical pattern, and range for example from the description of single cutouts to description of the steel structure of the entire double bottom of a ship including tanktop, floorplates etc. (fig. 3).

Central in this context is the above mentioned library of standard details which includes brackets, cutouts and holes, all of which are coded as ALKON norms. The various output-norms generate papertape for drawing and cutting of plates, and give relevant data for material ordering, weldlengths, centers of gravity etc.

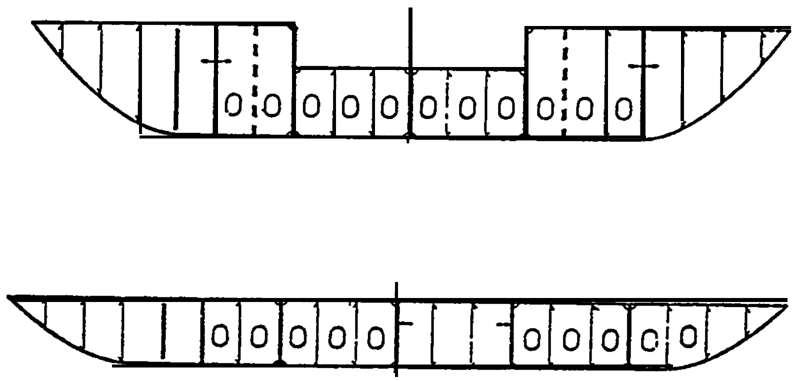


Fig. 3 : Floors

As concerns ships, an extensive system of norms is available. The normsystem is also quite flexible. An example of this is how the Aker Verdal Yard managed to increase efficiency for some activities in Jackets design. Based on AUTOKON norms, ten activities were coded. (Fig. 4).

After a few weeks the first norms were actually used in production preparation. The norm which generates the template for the cutting of truss connections (activity 8) produces a template demanding a total manhour of 20 to 30 minutes. Manually a good craftsman would manage 2 to 3 templates a day.

The accuracy obtained using a numerical method was far better and a substantial saving and better product quality was registered. Let us just mention that in 12 leg Jacket which has been built there were 560 such templates. The tubes in the Jacket had a diameter of up to 1.5 meters and a platethickness of up to 70 millimeters. The actual truss-connections may be very complex often with tubes intersecting eccentrically.

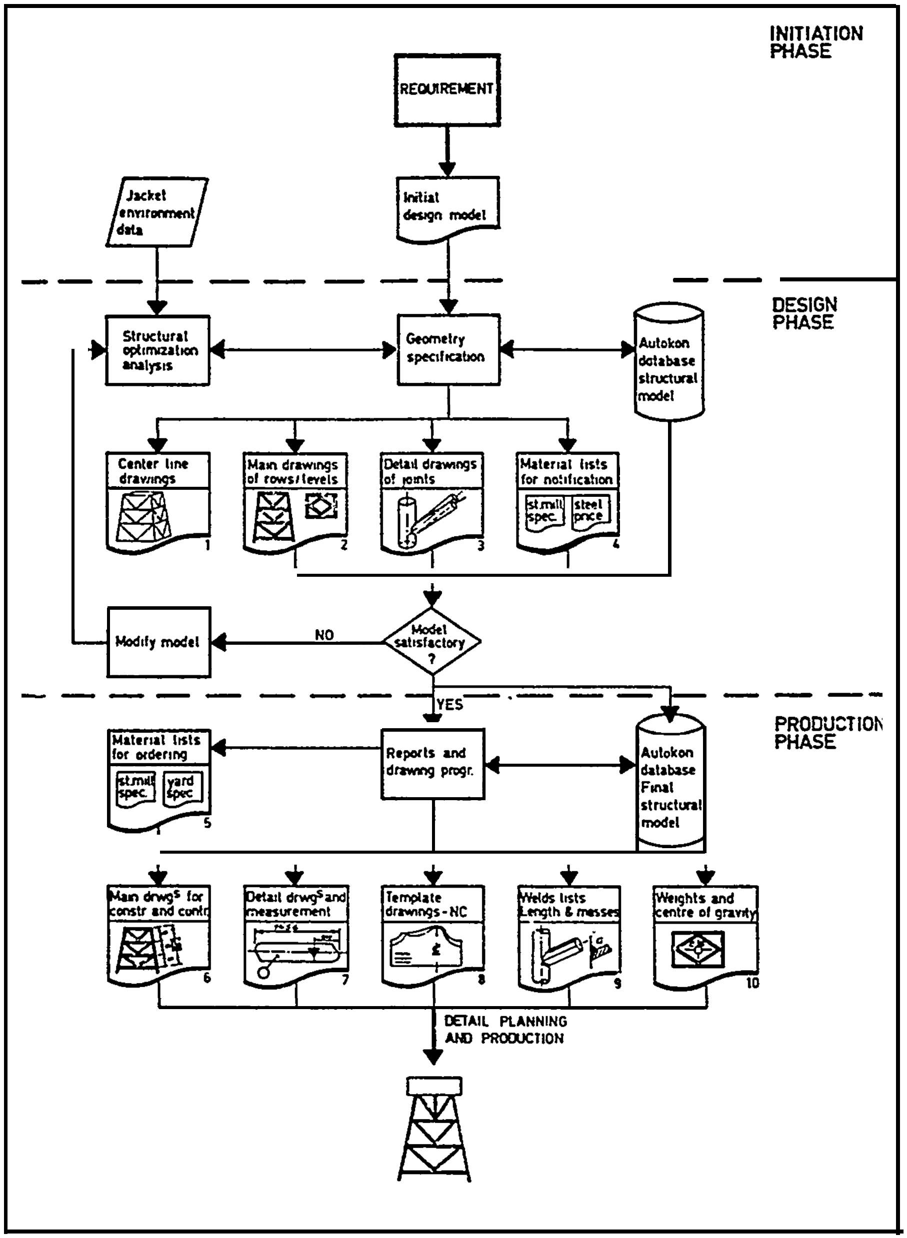


Fig. 4 : Jacket design

4. CURRENT DEVELOPMENT

There are currently two major development projects going on in SIAG:

- AUTOFIT which aims at the outfitting aspects of design and production of ships and offshore structures (not treated here).
- Interactive AUTOKON (IA) which aims at the design and manufacture of large steel constructs (ships' drilling /production platforms and other offshore structures).

IA includes a wide variety of applications, some of these presently covered by the AUTOKON system. We look at this new development with the intent of producing a technical information system. The crux of this system is the product model which conveys information to various analysis programs, other information systems or directly to the users (see fig.5).

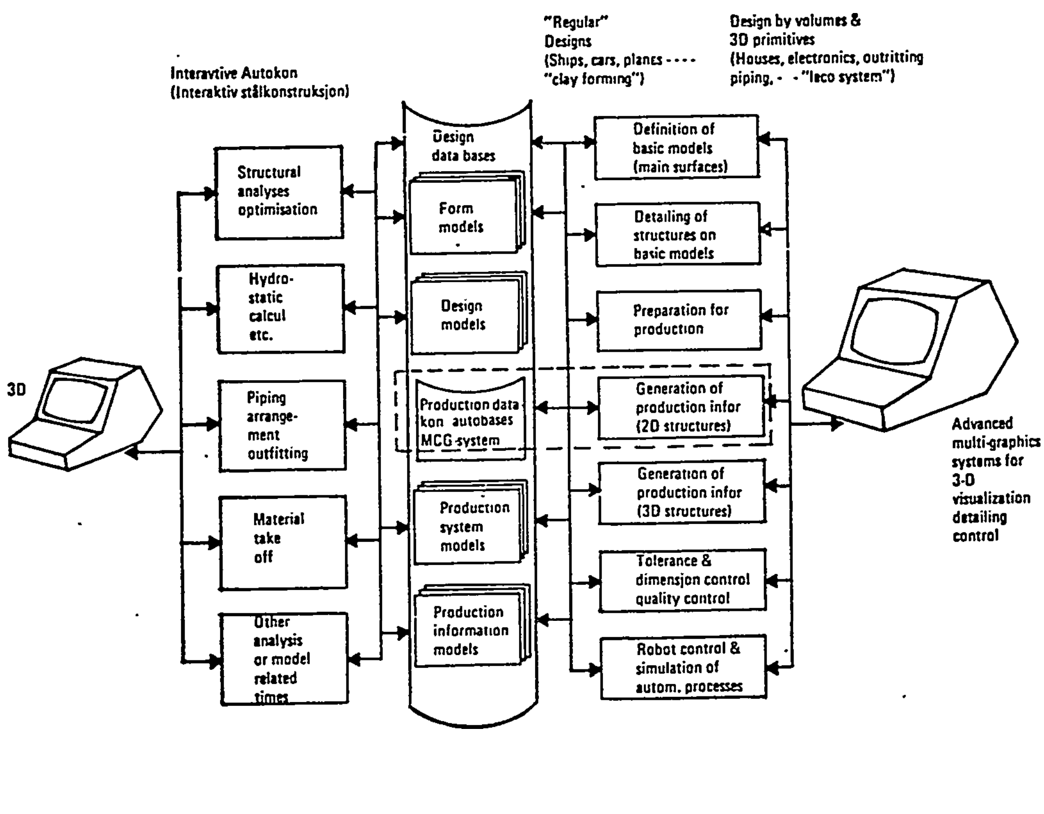


Fig. 5 : Interactive AUTOKON

UPresently (1977) the effort is directed at;

a) Design of the product model. The subsequent sections will discuss two aspects of this product model:

   1) Its ability to handle the iterations in the design process (changes).

   2) The interface with the human user.

b) Design and implementation of the first application programs.

The experience in ship design is that more than 50% of the manhours is spent on preparation for production. This includes the generation of shop drawings, definition of parts to be tooled etc. These key applications are therefore given high priority.

The applications include:

- An interactive part coding system

- A general purpose drafting tool.

- An interactive nesting system.

- A system for material specification.

The nesting system is presently (1977) used in production, temporarily using information provided by AUTOKON.

4.1 Limitations of Batch Systems

Today we produce a fairly complete basis for production using our batch systems. This information is produced spending less manhours than by manual methods. The results are also significantly better.

It is quite clear, however, that we have now reached a practical limit as concerns flowtime using such systems.

This is partly due to the wide variety of products which does not allow standard norms at a very high level.

Also our ambitions as concerns the scope of our information system has increased. We now want to include a large portion of the information flow in design and work preparation. In the following some of the objectives of our new system are discussed.

4.2 Availability of Information

We distinguish between three categories of information users. These impose different demands on format and presentation of information.

1. The draftsman or designer. His demands as regards communication with the system are particularly difficult to satisfy. This aspect is discussed in a later section.

2. Analysis program/systems. The trouble with these are their different requirements for data representation. We have no intention of making large scale changes to the analysis programs. Yet the information system must provide the relevant source data, geometry, topology and other information for these programs. (Our solution to this incorporates procedure models, reference 4).

3. Other information systems. Such systems are in operation today in fields like material administration and piping/ outfitting. There is need for a varying degree of intergration and interaction between such systems. Although these will still have separate data bases we intend to make them satellites in the same information environment.

4.3 Common Source for Information

The system will act as a communication device in the widest sense.

Information coming from one department will be immediately available in other departments. Different but mutually dependent tasks are thus linked closer together. Repetitive build up of the same information for different tasks is avoided.

4.4 Information Consistency

This is a major problem in manual information systems. Interdependent information is built up in different locations which in itself is a source for errors and inconsistencies. Changes typical to any design process add to the problem. In real life, drawings coming from only one department or even one draftsman are often inconsistent. In our automatic information system we aim at using the same source model for a large number of different tasks. Updates added to this central model will thus be immediately reported and available.

Furthermore, improved internal consistency is implicit in the structure of the model.

- The model produces 3D as opposed to 2D drawings.
- Topological description takes care of the relationships (connectivity) in the model. This also ensures that the consequences of changes are automatically taken into account. See next section.

4.7 The Change Oriented Product Model

A particular design is never really finished even if at some time there is a decision to build it. The process of design consists of a series of iterations aiming at some ideal product. In the batch systems the inability to respond to changes is a severe limitation which influences the lead time.

A particular problem is the influence of one change on other parts of the structure. A small change in the hull shape may effect hundreds of details as concerns shape and position. The number of adjustments to the geometry of structural details is error prone and very time consuming if done manually. How shall we deal with this? The effect we wish to obtain is perhaps best illustrated by the following.

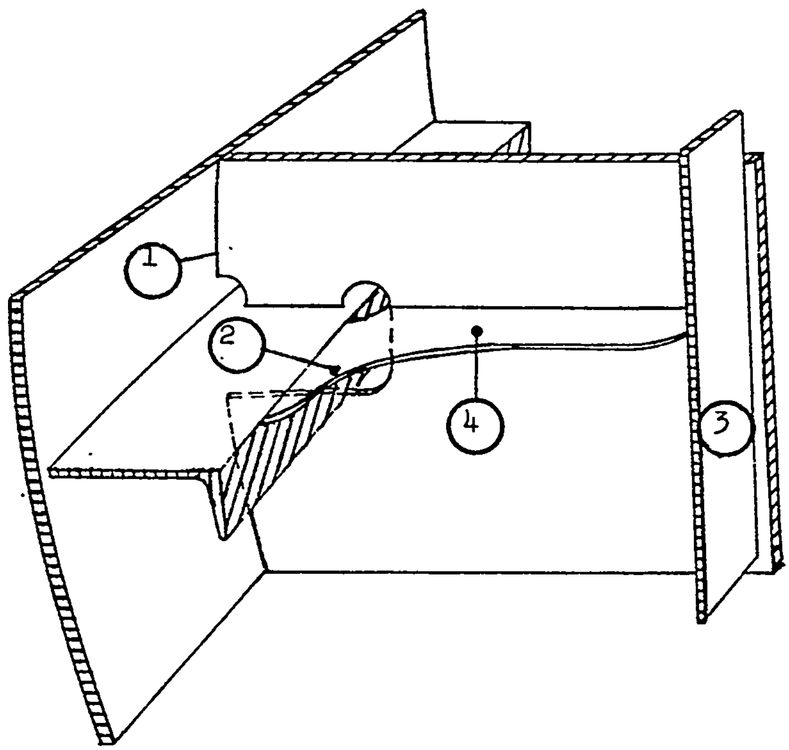


Fig. 6 : Structural dependence between surfaces and details.

In fig. 6 we have for example started off with a description of the shape of a ship hull. This hull may be defined in a variety of ways, but for the sake of argument the representation may be a **set of transverse frames (1) .** The important point is that the longi**tudinal frame (2) and the flange of the web frame (3) are defined** relative to the hull description. This means that primarily the data base contains a description of how (2) **and (3) are derived from the hull** description (1) **for example by a reference to a parallell routine** and the relevant parameters (parallell distance).

Furthermore, the bracket (4) is again defined relative to (2) and (3) Note that even if the geometry of (1) has not yet been described, the other feature may.

The purpose of the product model is to describe the product by identifying its functional entities and their relationships or "connection structures". These connection structures we call the topology of the product The topological description is separate from, but may refer to the geometrical description of primitives. In cases of geometrical changes the topological description refers to sufficient information to generate the new geometrical solution. This approach has the following advantages:

- Only a minimum of geometrical data is needed to describe the structure (minimum of data redundancy). Thus it means less work in the initial definition of the product.

- The descriptions of topology and geometry are separate and independent of each other which means that for a ship the internal structure may be defined prior to having defined the hull shape. More generally this allows flexibility as concerns the work sequence in a typical engineering design process (fig.7).

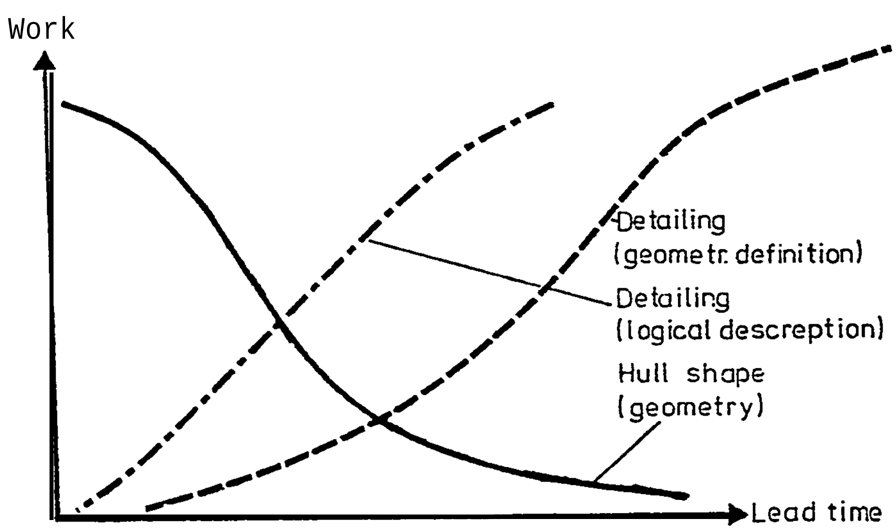


Fig 7 : Reduction in lead time.

All the geometric consequences of a change in scantling "(the most typical change) will inherently be taken care of without additional changes to the data base. The ability to handle changes and updates is certainly a major problem area. The topological description should reduce this problem to a minimum giving a change oriented system.

- Additional or alternative geometric representations are easily introduced. This is due to the fact that the major part of the product description is geometry independent and therefore does not change.

4.6 User Communication

The dialogue between the designer and the system is the key to user acceptance. This represents the face of the system and a major usability factor.

It is a problem which concerns hardware as well as software. The basic reason for the concern with this problem is on one hand the amount of information needed to describe our type of product in detail and on the other the amount of verification necessary. The number of structural details (pieces) in a large tanker is on the order of 100,000. The solution is partly found in the use of interactive and graphical methods.

In hardware terms this implies the use of mini computers and display screens.

Some points will illustrate the advantages to the designer who operates the system :

The work procedure is simple. There is a direct dialogue which eliminates the traditional punching forms, card decks, input, waiting etc.

The communication language is simple.

- Sketches and drawings as well as visual symbols are natural means of communication for engineers and draftsmen. (Our draftsmen are definitely reluctant to accept systems which require large amounts cryptic codes).

- There is a pronounced need for continuous verification of results (1 - 2 hours is often too long to wait for an error message which turns out to be trivial).

- The draftsman often needs the ability to make decisions based on intermediate results.

These points promise greater efficiency, but will also shift the emphasis from the handling of the system itself to more creative aspects of design - a more satisfactory work situation.

ACKNOWLEDGEMENT

We are indebted to F Lillehagen and J. Øian of the Central Institute for Industrial Research and P. Sørensen, S.A. Hansen and F.v. Cuilenborg of Shipping Research Services, all of whom have contributed to the projects and this paper.

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NEW FEATURES FOR REAPS AUTOKON

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Chicago, Illinois

Ms. Taska is a Research Mathematician at IIT Research Institute. She provides technical support, maintenance and enhancement of the REAPS AUTOKON System. This entails developing improved versions of the system, processing customer requests, and releasing new versions of the system for various computer installations.

Ms. Taska has a B.S. degree in Mathematics from the Illinois Institute of Technology and is pursuing an M.S. degree in Computer Sciences also at IIT.

I. Background of REAPS AUTOKON

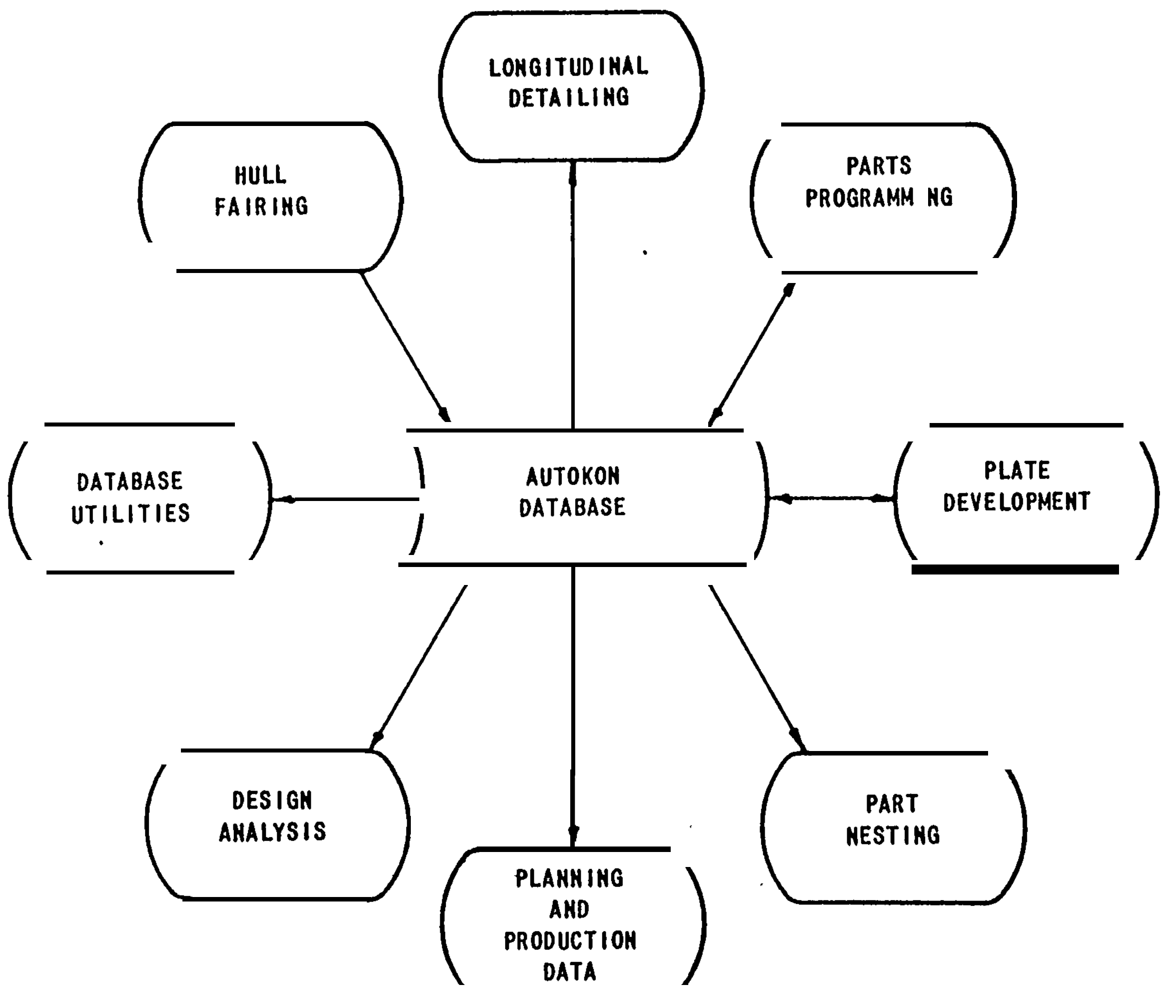
REAPS AUTOKON has emerged over the last three years as a valuable production tool in shipbuilding. Having its roots in the AUTOKON-71 System developed by Shipping Research Services (SRS) of Norway, REAPS AUTOKON consists of twelve independent computer programs communicating with a common database.

(SLIDE 1)

The REAPS Technical Staff maintains and enhances this system, which is available under a licensing agreement to all REAPS participants. Some of the most recent developments are discussed in this paper.

II. Enhancements to the ALKON Module

About a year ago, the REAPS program brought together a group of shipyard personnel, involved at the working level with AUTOKON, under the title of the Norms Enhancement Task Group. The purpose of this group was to exchange ideas, air complaints, and otherwise suggest improvements for the application of ALKON to parts programming. As a result of these initial meetings, the norms library was reviewed in detail, and significant modifications were made. Experimental Version BX1, which incorporated the Task Group's improvements, was released in November for incorporation into the database. In addition to that activity, two projects that significantly improve ALKON and respond to the user's needs have been spawned: Simplified ALKON and the conversion of some norms to inline code. A description of those projects follows.


LONGITUDINAL DETAILING
HULL FAIRING
PARTS PROGRAMM NG
DATABASE UTILITIES
AUTOKON DATABASE
PLATE DEVELOPMENT
DESIGN ANALYSIS
PLANNING AND PRODUCTION DATA
PART NESTING

1. Simplified ALKON

Whenever REAPS AUTOKON is implemented at a new yard, personnel must undergo a period of orientation and training to learn to use the system's features. Feed-back from yards who have attempted to teach ALKON to new part coders indicates that learning the ALKON language seems to be one of the more difficult tasks for persons unfamiliar with programming techniques. Even for programmers, the principles of parts definition can become obscured by the complexities of the language and I/O syntax requirements. For an experienced user, the flexibility of ALKON is a desirable quality, but the beginner needs a simpler, more basic, approach to parts specification.

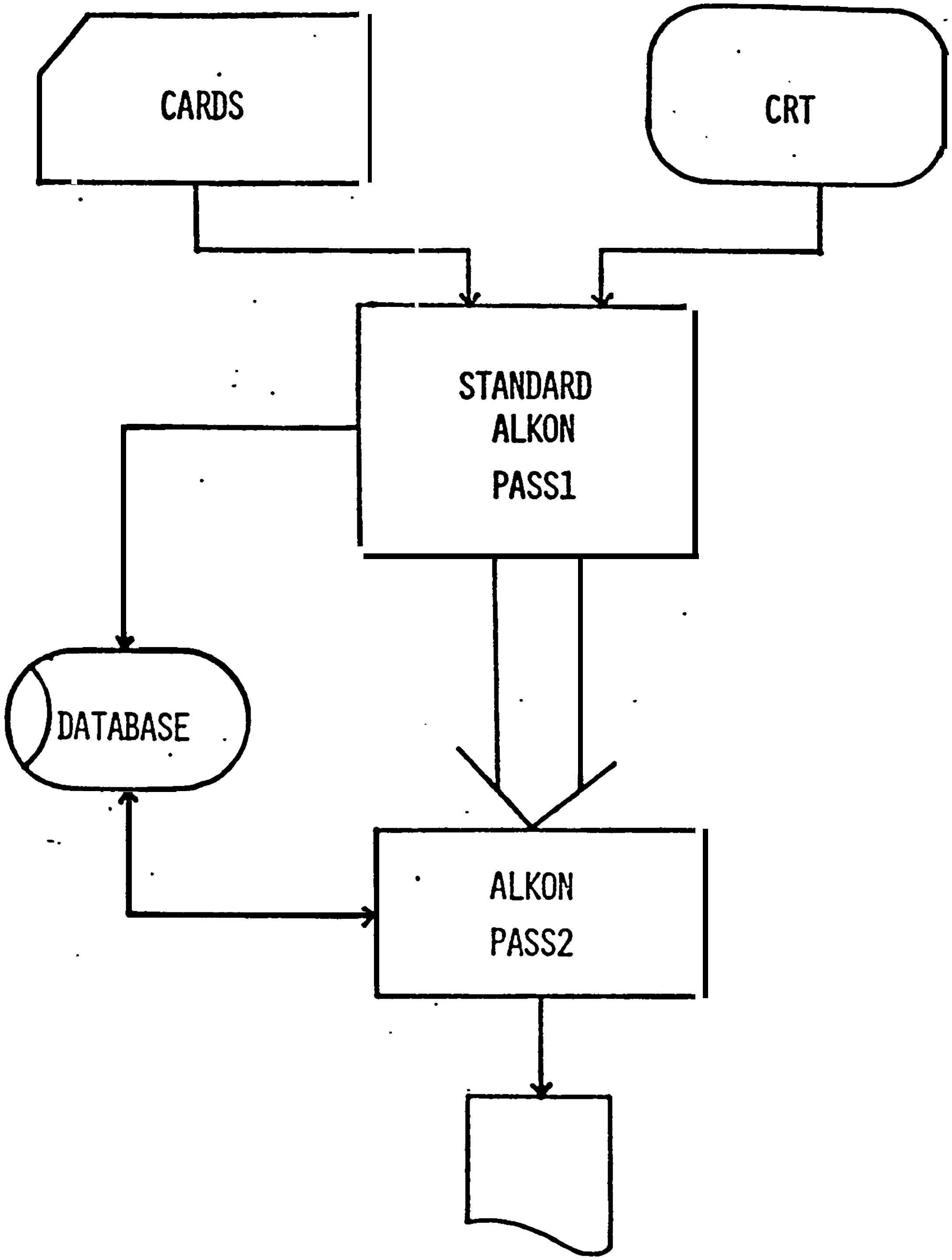
Simplified ALKON, now in its second release, has been designed and implemented through the combined efforts of the REAPS Technical Staff and yard personnel to eliminate some of these learning difficulties.

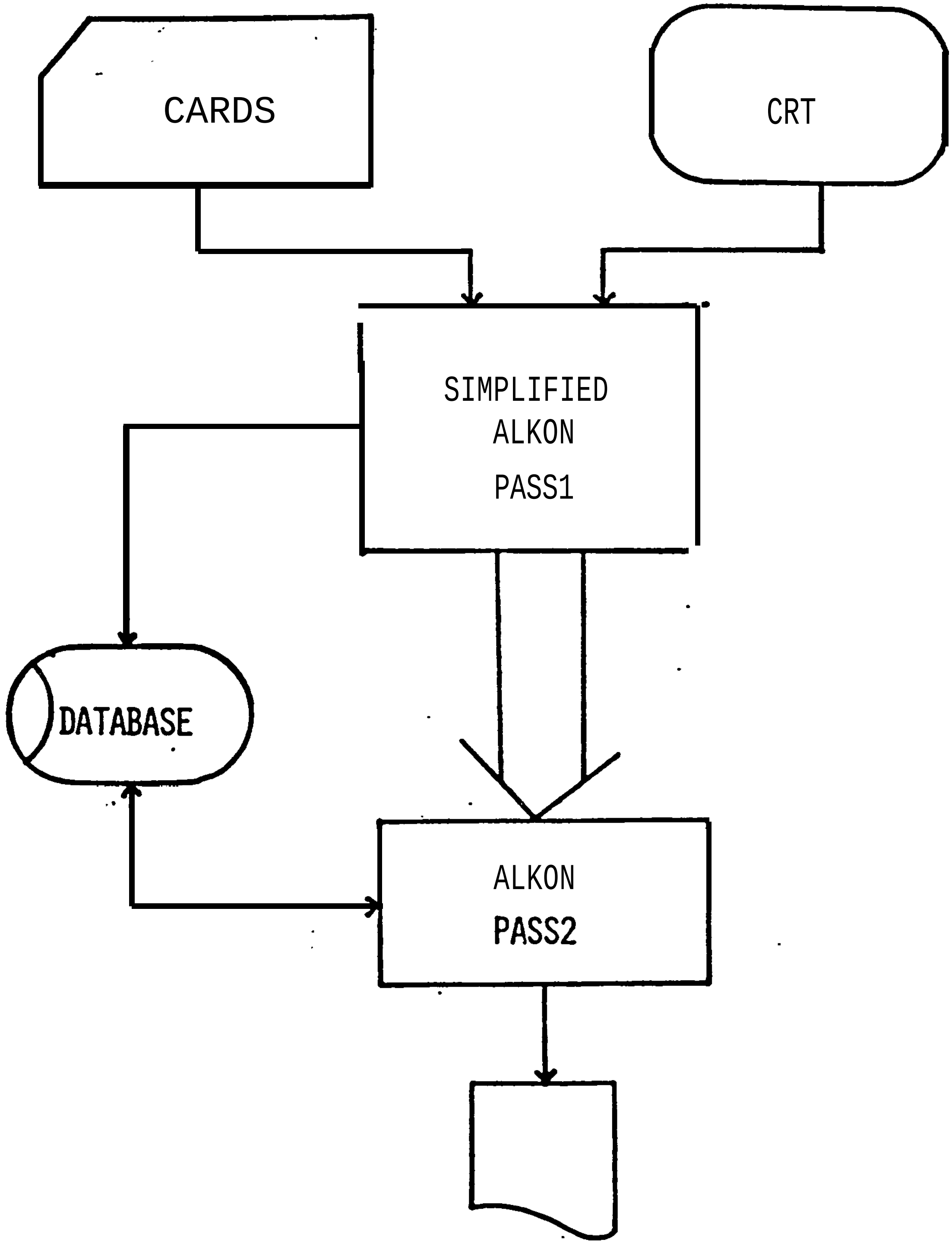
Standard ALKON accepts input from cards or CRT. Input is first compiled by PASS1, then executed by PASS2. Simplified ALKON works in exactly the same way, with a modified PASS1. Modifications to ALKON were all limited to the compilation stage to minimize the processing overhead.

(SLIDES 3A, 3B)

It is, as the name implies, simpler to use Simplified ALKQN than standard ALKON, The user gives shorter and fewer commands to accomplish part definition, All list, buffer, and matrix management is handled through defaults. The user can concentrate on geometry rather than on form.

(SLIDE 4)


CARDS
CRT
STANDARD
ALKON
PASS1
DATABASE
ALKON
PASS2


CARDS
CRT
SIMPLIFIED
ALKON
PASS1
DATABASE
ALKON
PASS2

SIMPLIFIED ALKON

- SIMPLER ALKON
  - DEFAULTS USED
  - SHORTER COMMANDS

  Ž FEWER COMMANDS

- CAPABLE
  - FULL GEOMETRY
  - SAME DATABASE

- LEARNING TOOL
  - SIMPLE MODE, OR

  Ž ALKON MODE
  - SWITCHABLE

Since Simplified ALKON is implemented on the Standard ALKON PASS1 compiler as a switchable option, it is every bit as capable as ALKON because it is ALKON with a new appearance. The same geometry specifications are available, and all database interfacing remains unchanged.

Fulfilling its original intent, Simplified ALKON is a learning tool. It is option-controlled, meaning that the user can operate partially in Simplified ALKON, escape into ALKON mode for extended capabilities, and then return to Simplified ALKON mode within a single manuscript.

A simple part description written first in Simplified ALKON and then in Standard ALKON points out the advantage.

(SLIDE 5)

Benchmark executions of Simplified ALKON, ALKON running under modified PASS1, and standard ALKON are given in this slide.

(SLIDE 6)

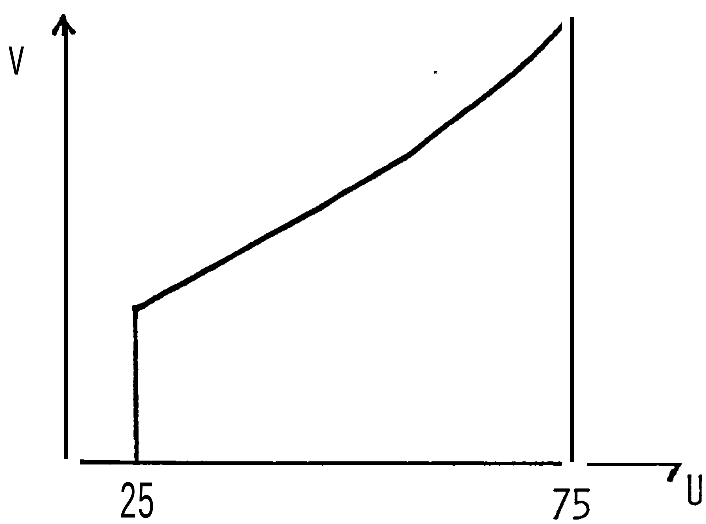
Bernie Breen of General Dynamics will present a paper detailing their experience with Simplified ALKON. The GROTON yard has been the test site for development of this tool.

2. Norms to Inline Code Conversion

A second activity suggested by the Norms Enhancements Task Group has been the conversion of costly norms into ALKON commands. The primary objective of this project has been to provide new capabilities in the ALKON system where certain frequently used command combinations, often embodied in norms, may be handled in a more efficient manner. This would consequently simplify part programmer re-

```
PC 900001′ YN 456′
TFR 25′
SPT (+25+0)
Al = 90′
SL:DIR(+A1)
INT′ CON ' INT(+75+50)
B1 = 90′
SL:DIR(+Bl) EPT(+75+0)
NCOUT′
```

SIMPLIFIED
ALKON




```
NEW ALIST(50)
NEW BLIST(50)
NEW CLIST(50)
SBUF′
TEMP RBUF′
STRT TXT′
EDIT 1 (PART NO. 900001
  PROCESSED FOR HULL NO .4566
END TXT′
PRINTTXT′
TFRAME(25)
AT SHELL′
FETCH LCON ‘
FETCH LTAB′
STRT RGEO′
SPT(+25+0)
Al = 90′
SL:DIR(+A1)
INT′ CON′ INT(+75+50)
B1 = 90′
SL:DIR(+B1) EPT(+75+0)
END RGEO′
PRINTCON′
NCCON′
STORE(+5+0+900001+0+0+0)
```

ALKON

	SIMPLIFIED ALKON	ALKON "B"	% CHANGE
MANUS 1	1,483	1,112	26%
MANUS 2	1,155	1,209	-5%
MANUS 3	1,241	1,062	15%

quirements and reduce computer costs.

Eleven norms were selected for conversion to ALKON commands. These norms are frequently used, straightforward, and short combinations of ALKON commands.

Because of their simplicity, it is not expected that the user would ever have a need to make modifications, or to utilize the ALKON traceback debugging feature, which makes norm writing more desirable than inline coding in some cases.

In addition to these eleven converted norms, two more norms were streamlined by the improved coding.

Benchmark manuscripts comparing old norm calls with new inline calls in a standard manuscript show significant savings using the inline coding. This slide shows a table of the benchmark results.

(SLIDE 7)

Based on the satisfactory performance of these modifications, Norm Enhancement Task Group members evaluated all standard norms on an individual basis and drew up a prioritized list of norms for future streamlining.

(SLIDE 8)

III. Maintenance Activity Report

Regular maintenance of the REAPS AUTOKON System by the Technical Staff encompasses four areas of concentration: implementation of REAPS AUTOKON, Analysis Request processing, documentation modifications, and Standard Version C.

NORMS

-VS-

INLINE CODING

	ALKON "B"	INLINE	% IMPR
MANUS 1	1.07	,917	15%
MANUS 2	1,449	1 , 211	16%
MANUS 3	,888	. 634	29%

MANUS

```
NEW  ALIST(1(0)
A1=2001   A2=4501   A3=501   A4=2501   A5=4501   A6=5001   A7=4001   A8=2501
PRLIST  (ALIST+1+0+l+8)                                        COMM(***]
COMM (TEST 1 OF EFFICIENCY OF INLINE CODE)
AXIS(+0+0+0)                                                   COMM(***)
TEMPL I                                                        COMM(***)
SPT(+A1+A1)
SL1TG[+A1+A2)
CTR:  RAD(+A3)   CNT(+A4+A5)
CTG(+A4+A6+A7+A6)                                              COMM(***)
CIR:  RAD(+A3)   CNT(+A7+A2)
CTG(+A2+A2+A2+A4]                                              COMM(***)
CIR:  RAD(+A3)   CNT(+A7+A4)
TG(+A5+A1)    SL:EPT(+A1+A1)
E N D    L G E O I .
PRINTCONl
```

•

NORM ENHANCEMENTS

UNDER DEVELOPMENT

GENTAB 2	DIST 1
INDECK 0	PVAL 1
INLONG 0	PVAL 3
INSEAM 0	CUTO 50
SL 1	FUN 2
TG 1	FUN 4
TG 2	MARK 0
ENDGEO 0	PVAL 4
	PVAL 5
	PVAL 6

INLINE WORDS UNDER DEVELOPMENT

PVALL xLIST, yLIST (zLIST)

ELSAVE xLIST yBUF (MATRIX)

1. Implementation of REAPS AUTOKON

Currently, REAPS AUTOKON is being maintained on three major computer installations: the UNIVAC 1108, the IBM 370, and the Honeywell 6080.

During the past year, the Technical Staff received the Bethlehem Shipbuilding Base Version of AUTOKON-71 and implemented it on a local IBM commercial machine. Updates were made to that version to bring it up to par with the UNIVAC 1108 Standard Version B of REAPS AUTOKON.

The Technical Staff is currently implementing Newport News Shipbuilding's Honeywell version of AUTOKON on a local Honeywell commercial machine. Several modules have been executed and all indications are that a successful implementation will conclude within the next few months.

2. Analysis Request Processing

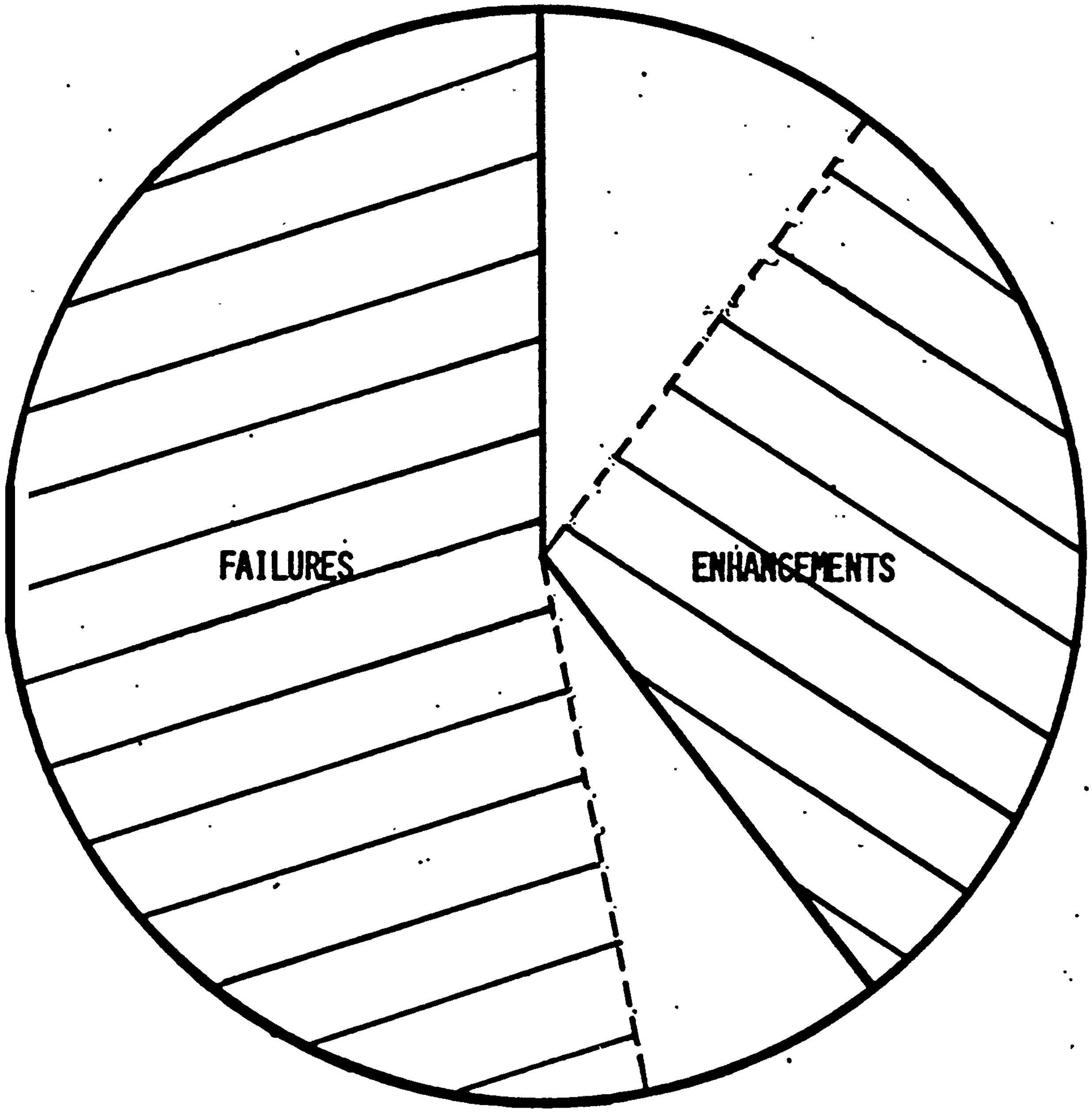
Concurrent with the support activities described above, continued maintenance, i.e., resolution of system failures and incorporation of minor enhancements, occurs throughout the year. The to-date totals on Analysis Request (AR) processing appear in this table.

(SLIDE 9)

3. Documentation Modifications

Over the past year, all five volumes of the REAPS AUTOKON User Manual have been updated to correspond to Version B of the System.

AR PROCESSING



	FAILURES	ENHANCEMENTS
REC'D	64%	35 %
RES'LD	89%	69 %

4. Expectations for Standard Version C

In August of this year, the third annual update to REAPS AUTOKON will be generated, creating Standard U.S. Version C. Resolved system failures and enhancements are planned, as usual, for inclusion. In addition, the following items are planned for release:

- INLINE COMMANDS

AXIS	RND
PVALC	CTG
RELORIGIN	PRLIST
RELORIENT	CMPRSS
PERML	PVALL
PERMR	ELSAVE
TEMPL	
TEMPR	

- STREAMLINED NORMS

ROUT 408	DIST1
PVAL2	PVAL1
GENTAB2	PVAL3
INDECK 0	CUT050
INLONG O	FUN2
INSEAM 0	FUN4
SL1	MARKO
TG1	PVAL4
ENDGEO 0	PVAL6

- REVISED NORMS LIBRARY
- SIMPLIFIED ALKON
  - NEW VOCABULARY 10
  - AUGMENTED NORM LIBRARY
  - MODIFIED PASS1
- RESOLVED FAILURES
  - DUP
  - AUTOBASE
  - LANSKI
  - FAIR
  - DRAW
  - ALKON
- ENHANCEMENTS
  - NEW IF COMMAND

USER EXPERIENCE WITH REAPS SIMPLIFIED ALKON

Bernard J. Breen
General Dynamics Corporation
Eastern Data Systems Center
Groton, Connecticut

As Management Systems Specialist, Mr. Breen is responsible for all the Data Center supported CAD/CAM activities of General Dynamics' Shipyard divisions. He has been responsible for AUTOKON and related software since the system was first installed in North America in 1968 at General Dynamics.

Mr. Breen has a B.S. degree in Mathematics and Computer Sciences from Purdue University.

1. **WHAT IS ALKON?**

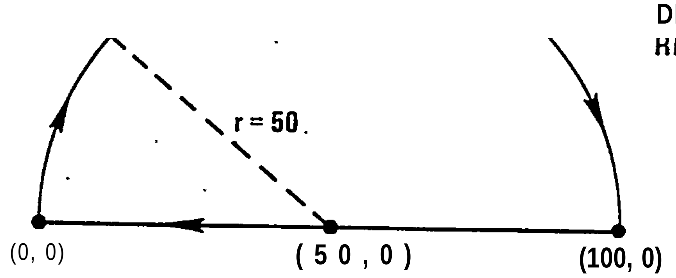
A PARTS GENERATION SOFTWARE SYSTEM

- AUTOKON 1: PARTS GENERATION
- AUTOKON '71/'76: ALKON
- REAPS: SIMPLIFIED ALKON

GENERAL DYNAMICS

2. SPT (+0+0)

CIR: CNT(+50+0)
RAD (−50) EPT (+100+0)
SL: EPT (+0+0)



GENERAL DYNAMICS

3. **WHAT IS SIMPLIFIED ALKON?**

- AUTOKON '71 ALKON
- AUTOKON 1 PARTS GENERATION
  - BY SOFTWARE ENHANCEMENTS TO AUTOKON '71
  - BY INCLUSION OF SPECIALIZED NORMS

GENERAL DYNAMICS

4. **SIMPLIFIED ALKON**

A METHOD OF OFFERING A RELATIVELY SIMPLE PARTS GENERATION LANGUAGE FOR N/C FLAME CUTTING DEMANDS WHILE SIMULTANEOUSLY. ALLOWING A SOPHISTICATED LANGUAGE FOR DESIGN AND ADVANCED MANUFACTURING REQUIREMENTS

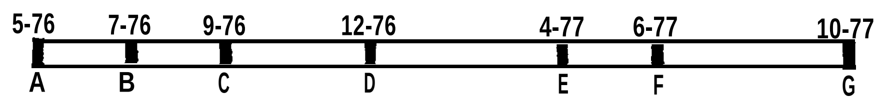
GENERAL DYNAMICS

HOW HAS SIMPLIFIED ALKON BEEN DEVELOPED?

- APPROVED AS A REAPS DISCRETIONARY DEVELOPMENT PROJECT IN 1976
- JOINT EFFORT BETWEEN IIT RESEARCH INSTITUTE AND GENERAL DYNAMICS CORP.

GENERAL DYNAMICS

IMPLEMENTATION SCHEDULE



A: PRELIMINARY SPECIFICATIONS
B: REAPS PARTICIPANTS' COMMENTS
C: REVISED SPECIFICATIONS
D: DISTRIBUTION OF BX2
E: REVISED REQUIREMENTS
F: DISTRIBUTION OF BX3
G: DISTRIBUTION OF BX4

GENERAL DYNAMICS

WHY SIMPLIFIED ALKON?

- TRAINING
- TURN-AROUND
- ADDITIONAL CAPABILITIES
- SOFTWARE MAINTENANCE AND MODIFICATIONS
- COMPUTER MAINFRAME FACETS

GENERAL DYNAMICS

TRAINING

AUTOKON '71 ALKON

- BASIC - 6 WEEKS AT 20 HOURS/WEEK
  DOES NOT ALLOW FULL CAPABILITY NORM CODER
- ADVANCED - 4 WEEKS AT 20 HOURS/WEEK
  INCLUDES CONCEPTS SUCH AS WIRE MODELS,
  GOES BEYOND CAPABILITIES OF AUTOKON 1,
  ALLOWS NORM CODING PENDING USER

AUTOKON 1 PARTS GENERATION

- 2 WEEKS AT 20 HOURS/WEEK
  FULL PRODUCTION CODER
  ALLOWS NORM CODING PENDING USER
  CAN BE LEARNED BY "HAMMER AND NAIL" LOFTSMEN

GENERAL DYNAMICS

TURN-AROUND

NUMBER OF JOB SUBMISSIONS REQUIRED
PER SUCCESSFUL MANUSCRIPT

- AUTOKON '71 ALKON: 3-5 SUBMISSIONS
- **AUTOKON 1 PARTS: 2-4 SUBMISSIONS**

GENERAL DYNAMICS

ADDITIONAL CAPABILITIES

ALL AUTOKON '71 ALKON FACETS ARE AVAILABLE TO THE AUTOKON 1 PARTS GENERATION CODER

GENERAL DYNAMICS

SOFTWARE MAINTENANCE AND MODIFICATIONS

- **AUTOKON '71 ALKON:**
  - **THREE-PASS SYSTEM**
  - **A DATA BASE RECORD INCLUDES ALL RELATED MATRIX DATA**
  - **REAPS/IIT RESEARCH INSTITUTE SUPPORTED**
- **AUTOKON 1 PARTS GENERATION:**
  - **SIX-PASS SYSTEM**
  - **A DATA BASE RECORD IS COMPRISED OF A SINGLE GEOMETRIC CONTOUR**

GENERAL DYNAMICS

COMPUTER MAINFRAME FACETS:

FACET	AUTOKON 1 PARTS	AUTOKON'71 ALKON	SIMPLIFIED ALKON
MEMORY	64K WDS	49K WDS	53K WDS
MASS STORAGE	2.2 MIL. WDS	1.7 MIL. WDS	1.7 MIL. WDS
CPU TIME:			
1 PART	13.6 SEC	4.6 SEC	4.8 SEC
5 PARTS	27.4 SEC	18.3 SEC	22.1 SEC
20 PARTS	81.6 SEC	60.6 SEC	75.3 SEC

GENERAL DYNAMICS

GROUP TECHNOLOGY AS RELATED TO THE SHIPBUILDING INDUSTRY

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Dr. Ham is Professor of Industrial Engineering and member of the graduate faculty. He teaches and conducts research in the areas of manufacturing processes, optimization and group technology. His past experience includes engineering, research and consulting positions for many companies involved in manufacturing.

Dr. Ham has B.S., M.S. and Ph.D. degrees in Mechanical Engineering.

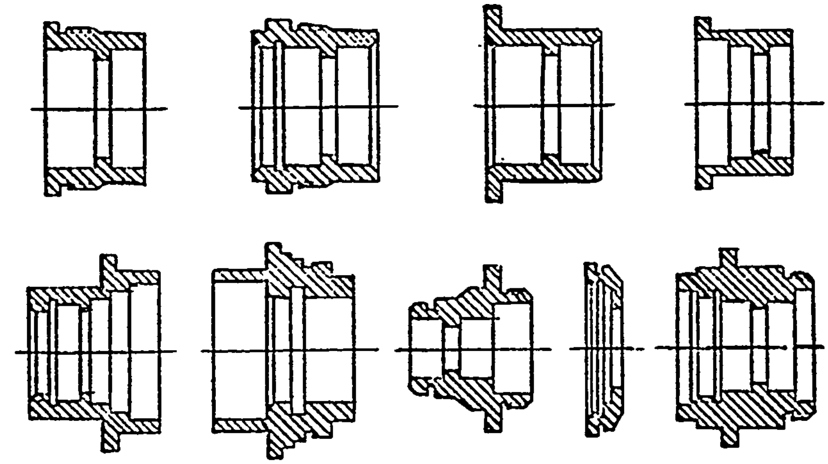
INTRODUCTION

A growing amount of attention has been turned to Group Technology which deals with the area of batch-type manufacturing for those who are engaged with small lot sizes and a variety of products. Development and implementation of integrated computer aided manufacturing (ICAM) will lead to rapid changes in U.S. manufacturing industry. It has been recognized that Group Technology is an essential element of the foundation for the successful development and implementation of ICAM through the application of the part-family concept.

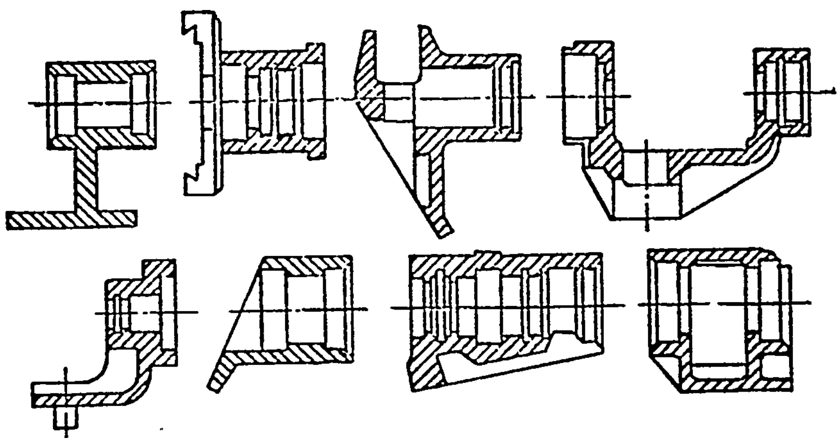
Group Technology is a manufacturing philosophy which identifies and exploits "the underlying sameness" of parts and the manufacturing processes. In batch type manufacturing, conventionally each part is treated as being unique from design to manufacture. However, by grouping similar parts into part families (Fig. 1) based on either their geometries or processes, it is possible to reduce costs through more effective design rationalization and design data retrieval, fewer stocks and purchases, simplified and improved production planning and control, reduction of tooling, and set-up times, flow line production by machine groups/cells, less in-process inventory, reduction of total through-put time, reduction of NC programming, a more efficient NC machine utilization. See Fig. 2.

The basic concept of Group Technology has been practiced in the U.S. for many years as part of "Good Engineering Practice" and "Scientific Management". For example, a coding system developed by F. W. Taylor (1) was used in the manufacturing industry as early as the beginning of this century. Many companies devised their own coding systems and have been using them for many years in various areas such as design, materials, tools, etc. There are numerous examples of machine groups or cells, group tooling devices, part family groupings and programming, etc. which have been in practice for many, many years in various sectors of U.S. industry. These practices and applications of Group Technology Concept's were identified under different names and in various forms of engineering and manufacturing functions.

In Europe, Group Technology also has been practiced in various forms and degrees for many years. Many countries took a new interest in Group Technology in the 1950's and 1960's. At that time coding systems were developed, machine cell concepts were practiced, and many excellent group tooling practices have been reported (2,3). Japan has been promoting Group Technology in order to improve its productivity since the 1960's (4). However, in the U.S., Group Technology has not received formal recognition and has not been rigorously



(a) Part family with similarity in shapes



(b) Part family with similarity in production operations

Figure 1, Examples of part family

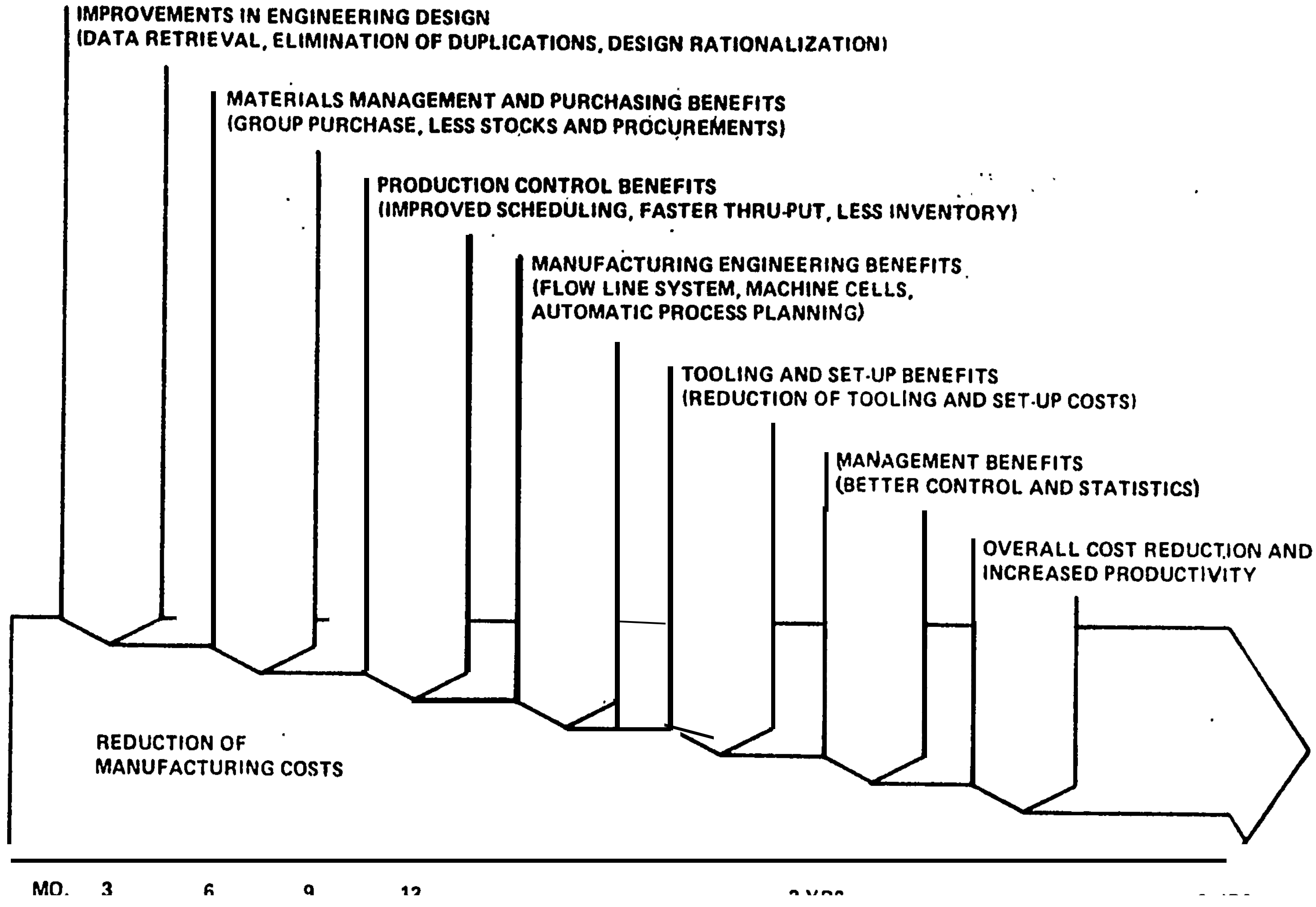


Figure 2, Reduction of manufacturing costs through Group Technology applications and approximate time required for implementation.

practiced as a systematic scientific technology. The most evident aspect of the U.S. manufacturing scene in the last few years is that it is undergoing a revolution through a critical self-evaluation for improvement of manufacturing productivity. This has led to an intensified effort in integrated computer aided manufacturing. This trend has stimulated a strong interest in Group Technology today since it provides the essential means for higher manufacturing productivity and for computer aided manufacturing, e.g. computer aided process planning, etc. (5, 6, 7, 8, 9).

One of the most important techniques in increasing manufacturing productivity is the economic incentive. Manufacturing normally contributes approximately 30% of the gross national product of modern industrialized countries. Yet in spite of that, manufacturing, although normally thought of as a highly productive and efficient activity, is not generally so. For example, this is clearly true of batch-type metalworking manufacturing environment. In the U.S. manufacturing industry, one of the significant facts to be carefully examined is the change in production trends. It has been estimated that in the next decade, about 75% of all industrial parts produced in the U.S. will be on a small-lot basis, as compared to about 25% at present (10). A recent survey on Group Technology applications in metal working in the U.S. (11) indicates that the average lot size is less than 50 pieces. The metalworking industry employs almost 40% of the total employment in manufacturing in the U.S. Thus, the potential for economic improvement of manufacturing by Group Technology is indeed not only tremendous now, but will grow with time.

It has also been reported that in batch-type metalworking shops, only about 5% of the total production time is actually spent on machine tools while the other 95% of the time is spent in moving and waiting for parts in the shop. Of that 5%, only about 30% is spent as productive time in cutting materials as shown in Fig. 3 (12). Therefore, major efforts should be made to improve this situation for higher manufacturing productivity. Improvements can certainly be achieved by proper implementation of Group Technology and by computer automated manufacturing.

Another area for improvement is more efficient utilization of expensive machine tools and work centers. To achieve the goal for implementation of computer automated manufacturing, this task is an essential requirement. Again Group Technology provides a key element toward this effort.

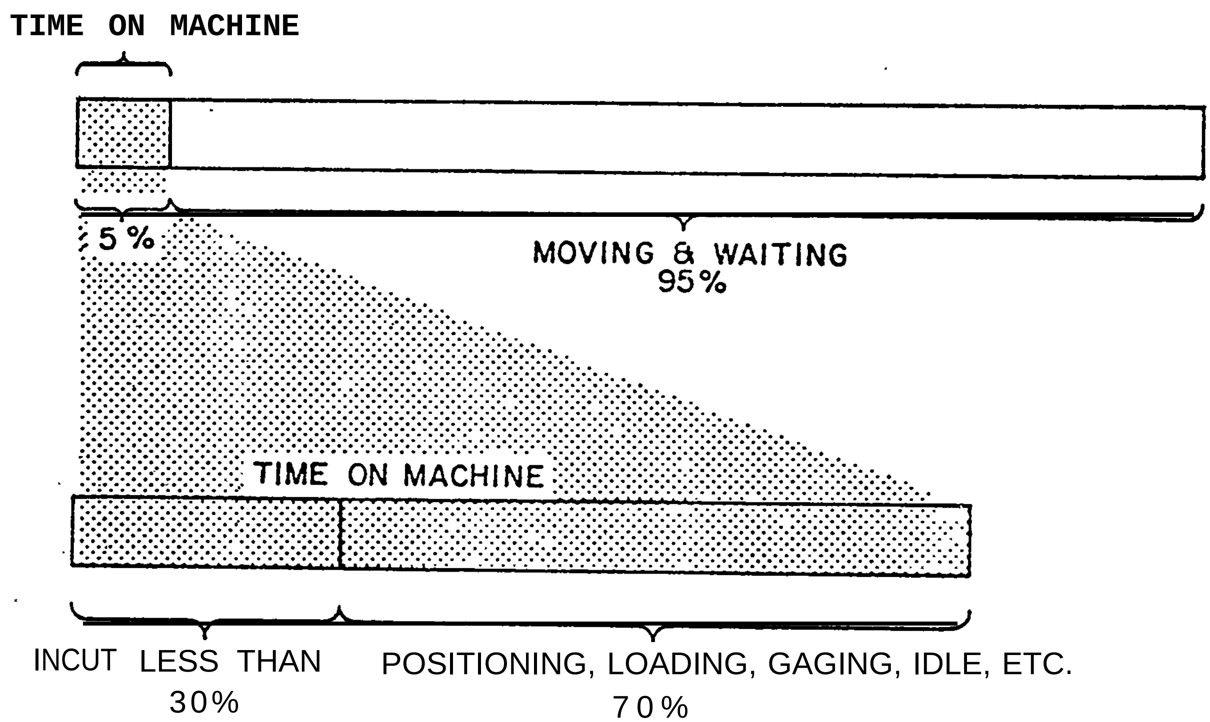


Figure 3, Percentages of the life of the average workpiece in batch-type metal-working production shops

A recent survey conducted by CAM-I (Computer Aided Manufacturing International Inc.) in April 1975 provides strong evidence of the importance of Group Technology applications for batch-type manufacturing industries, (figure 4 (13)) It can be concluded that Group Technology is one of our most important methods of solving present problems and improving manufacturing.

For these reasons, many companies in the U.S. who are related to batch-type component industries (e.g., aerospace industry) have become increasingly interested in Group Technology. The activities related to integrated computer aided manufacturing (ICAM), such as CAD/CAM and computer aided process planning (CAPP) provide more incentive four immediate interest in many sectors of U.S. industries. It is also interesting to note that many U.S. companies are also interested in Group Technology applications to justify their ever-increasing capital investments for expensive NC machines by more efficient machine loading through part family grouping.

PART FAMILIES

A part family or group is defined as a collection of related parts which are nearly identical or similar. They are related by geometric shape and size and by similar processing requirements. Alternatively, they may be dissimilar in shape, but related by having all or some common production operations.

The grouping of related parts into families is the key to the Group Technology concept. These families may be constructed in one of two ways as follows:

a) The first type of part family consists of parts which are similar in shape within a certain dimensional range and have most or perhaps all production operations in common.
b) The second type of part family consists of parts of dissimilar geometry but have a similarity in production operations.

The problem which immediately presents itself is how are the parts to be efficiently grouped into these families? There are three basic methods used to form part families, namely:

a) Manual visual search
b) Production flow analysis (Fig. 5)
c) Classification and coding systems (Fig. 6)

CAM-I
INDUSTRY SURVEY
(SUMMARY)

Japan	Europe	United States	Combined	PRIORITIES	Automotive	Electrical	Aerospace	Machine Tool	Research
4	_	_	_	Mfg. Data Base Design	4	1	1	1	
6	11	9	10	computerized Mtrl. Handling	9	11			1;
9	11	14	13	Comp. Controlled Transfer Ln.	1	12	1	1	12
3	9	13	12	Comp. Controlled Assy. Line Operations	8	9	11	10	1 0
10	7	8	5	In-Process Inspection	10	2		11	4
2	a	12	11	Die Sinking	3	8	10	13	9
7	6	2	4	scheduling	11	3	5	3	7
4	3	10	5	n/C Verification System	11	7	4	7	1
1	7	11	7	Automated Drawing Generation	2	8	9	● 12	5
3	4	5	3	Interactive Graphics	6	1	3	8	2
5	1	4	2	Group Technology	5	6	1	5	3
11	12	6	9	Adaptive Control (A/C)	7	10	3	9	7
8	5	7	8	DIrect Numerical Control(DNC)	13	4	2	4	3
12	10	3	6	Computerized Numerical Contxol	12	5	6	2	0

Figure 4, Summary results of CAM-I industrial survey (1975) on current manufacturing interests

(a) Original record from operation rout sheets

Machine No. \ Part No	A2	A3	A10	A11	A12	A16	A17	A18	A19	A20	A21	B1	B3	B5	B6	B8	B9	B11	C1	C2	C4	C6	C7	C9
042																								
404			✓													✓								
406															✓									
411	✓												✓								✓			
412					✓	✓	✓			✓	✓	✓							✓					
413				✓										✓										
416	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓			✓	✓
417									✓								✓							
420	✓		✓										✓			✓								
421								✓									✓					✓		✓
423		✓	✓										✓			✓								
424						✓	✓		✓								✓							
329																								
306								✓										✓						
304								✓										✓						
312								✓										✓						
445	✓				✓	✓	✓	✓			✓	✓					✓	✓						✓
446					✓	✓	✓					✓					✓							✓
447				✓						✓			✓	✓	✓					✓		✓	✓	

(b) After sorting families and groups

Machine No. \ Part No.	A10	B8	A2	B3	C4	C7	A3	A11	B5	B9	A19	A16	A17	A20	A21	B1	C1	C2	C9	A18	B11	C6	B6
423	✓	✓		✓		✓	✓																
416	✓	✓	✓	✓		✓																	
420	✓	✓	✓	✓																			
404	✓	✓																					
411			✓	✓	✓																		
413	Group 1							✓	✓														
417										✓	✓												
416										✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
412												✓	✓	✓	✓	✓	✓						
424										✓	✓	✓	✓				✓						
306																	✓						
421																			✓	✓	✓	✓	
306												Group 2								✓	✓		
304																				✓	✓		
312																				✓	✓		
406																			Group 3				✓

Figure 5, Example of Production flow analysis

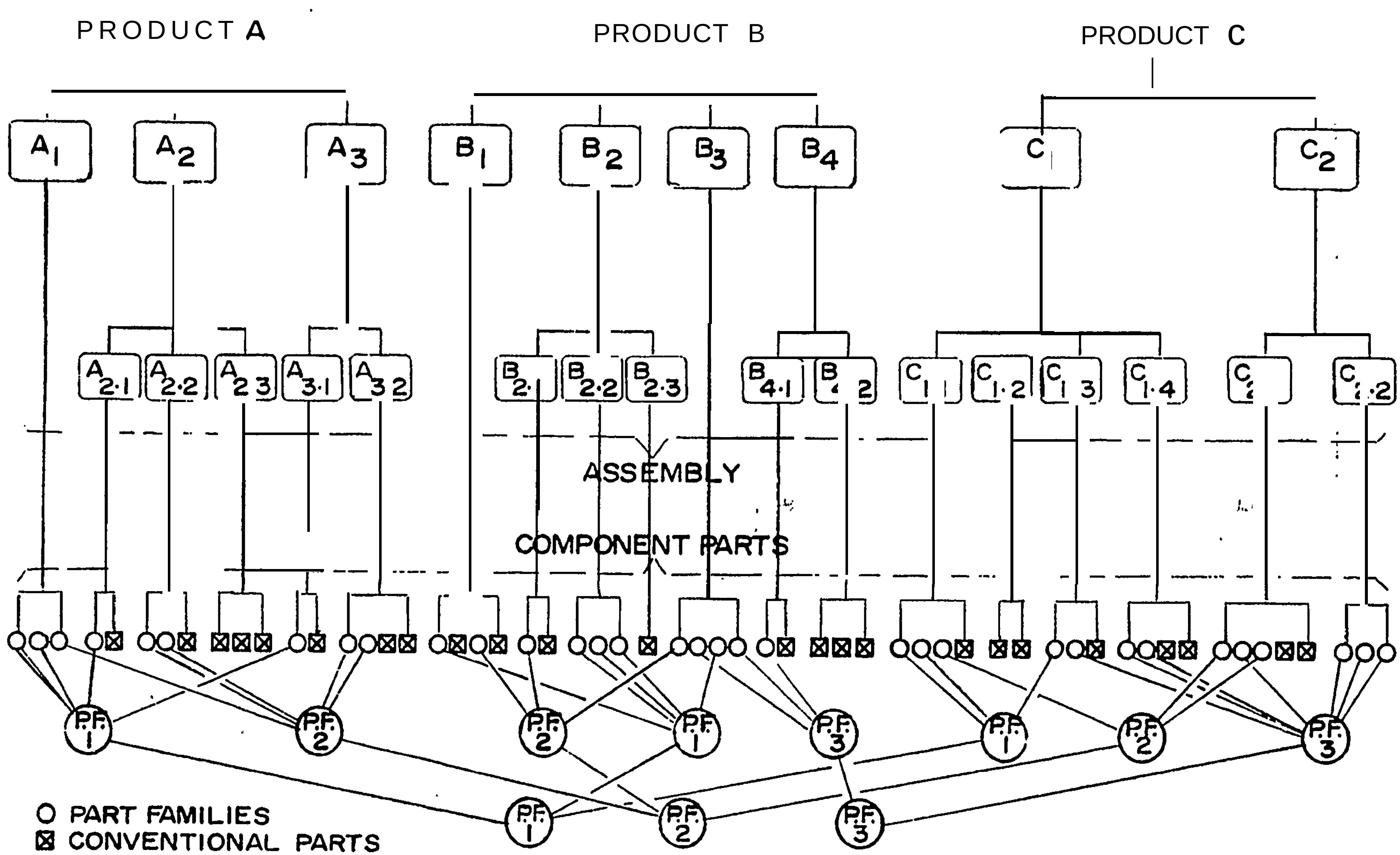


Figure 6, Schematic diagram for formation of part families

CLASSIFICATION AND CODING

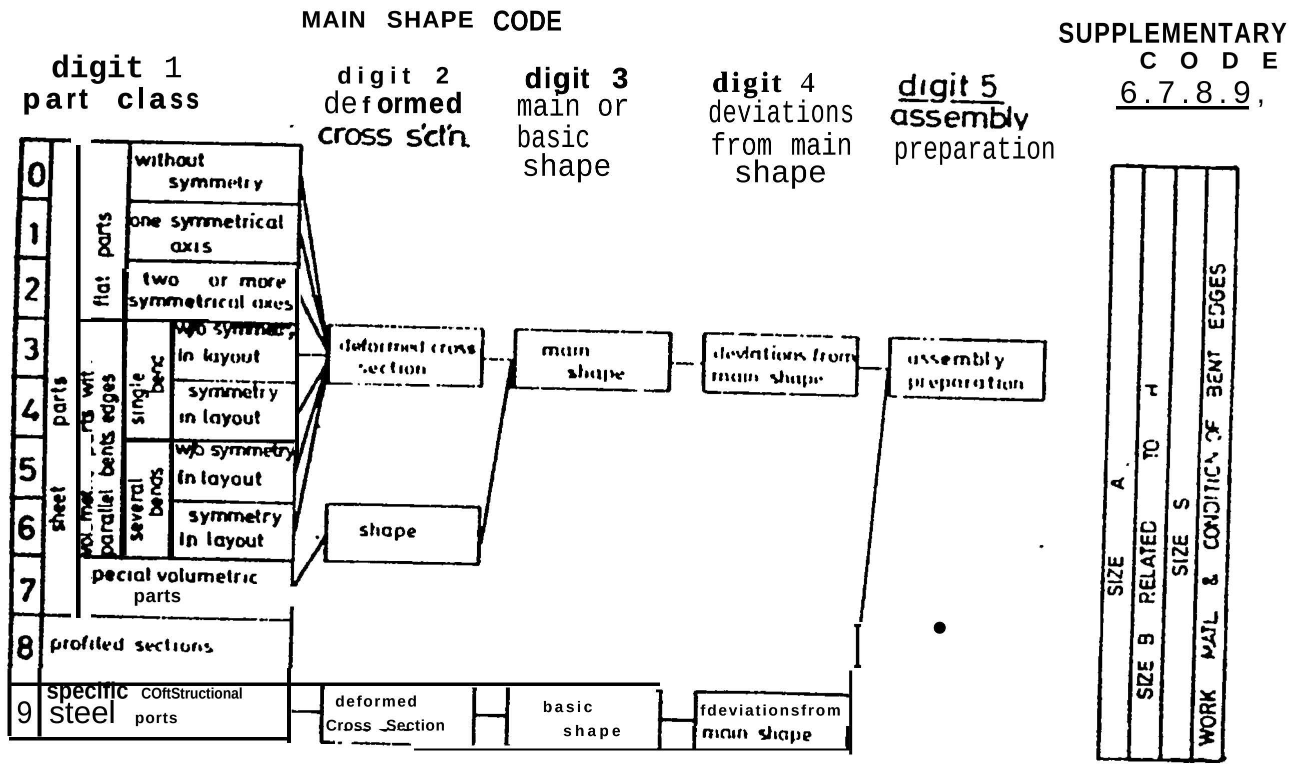
Classification is arranging items into groups according to some principle or system whereby like things are brought together by virtue of their similarities, and then separated by a specific difference. A code can be a. system of symbols used in information processing in which numbers or letters or a combination of numbers and letters are given a certain meaning.

There are many varieties of classification and coding systems being used around the world. The best coding system is one which is properly adapted to meet the specific needs of the company where it is being used. A company can devise its own unique system based upon publicly available systems or adapt a commercially available system to meet its needs. It is essential that an adapted system be applicable to and usable by all concerned departments in the company, including design, engineering, planning, control, manufacturing, tooling, management.

A well-designed classification and coding system for Group Technology implementation should meet several basic requirements. (Fig. 7)

DESIGN DATA RETRIEVAL

An important application of a good classification and coding system is in connection with design data retrieval and rationalization. Not only design information, but material specification, production planning and other production information can be readily available. All relevant production information can be retrieved for scheduling, group machining, group tooling and set-up. A classification and coding system also facilitates a part reduction and standardization program which can be valuable to the company as well as to customers of the company. It has been reported (11) that an average cost of introducing a new part into engineering and manufacturing systems is around $1,300 to $2,500 (average $1,900) per part. One company reported that about 2,500 new parts were released annually (thus an average of ten new parts every day), while about 30,000 active parts were in their design files. It can be estimated that the annual cost of new part introductions in this company approximates $4,750,000 per year (=2,500 parts x $1,900 per part). It is clear much can be saved by eliminating the duplication of parts thus reducing the number of new parts. It has also been reported that about 5 to 10% of new parts can be avoided by the proper use of classification and coding systems. Thus, the company re-



Developed in West Germany at Aachen Technical University around 1970. The coding system consists of five numeric primary digits and four numeric secondary digits. The code describes parts as sheet or profiled components and further defines them according to shape, cross-section and necessary preparation. The supplementary code covers main dimensions, thickness and material.

Figure 7, Example of sheet metal classification and coding system (23).

ferred to can save about $237,500 to $475,000 per year in the reduction of duplicated designs.

MACHINE GROUP

There are three types of plant layout, namely: a) line layout, b) functional layout, and c) group layout. In the practice of Group Technology, a group of machines for a part family or more may be formed such that it can perform all the operations required by the family or families of parts. The machines themselves are arranged in a flow line to minimize transportation and waiting problems. The result is very similar to a modern machining center. If conditions warrant, a machining center may be used instead of a group of single purpose machines. An example of a group layout of machine tools based upon the G.T. concept as compared with a conventional functional layout is shown in Fig. 8. This illustrates the advantages of a group layout.

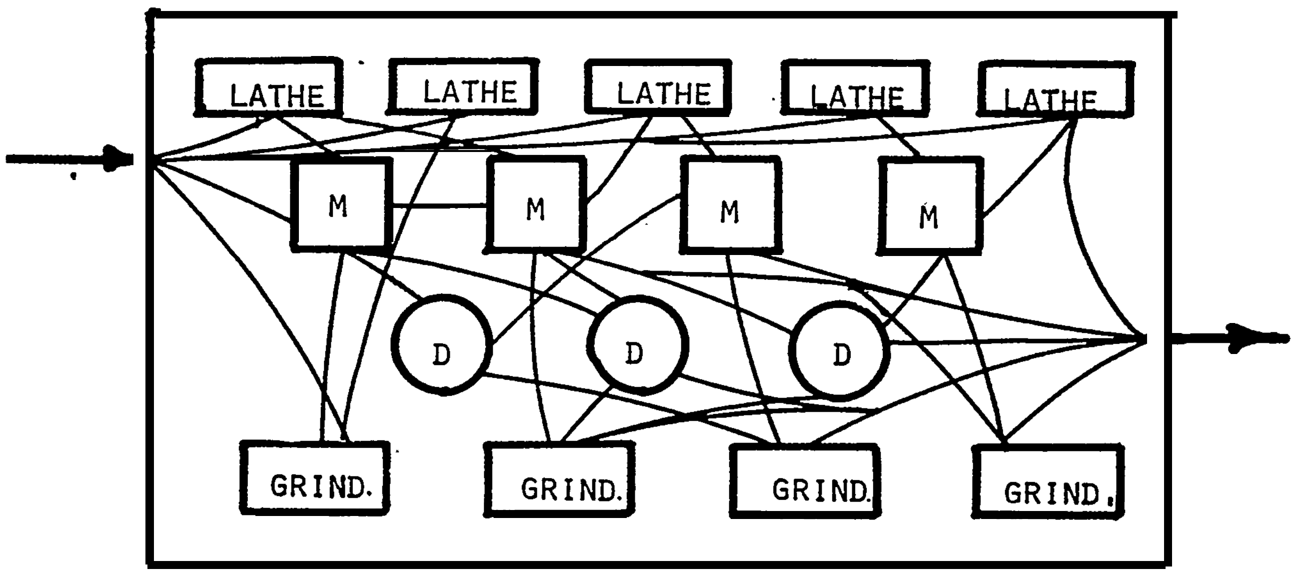
COMPOSITE PARTS

The composite component provides production aid for the application of G.T. in the standardization of parts, machine grouping, designing of group jigs and fixtures, the planning of group tooling set-ups, and standardization of process routings. Fig. 9 illustrates a group of parts represented by a composite component which possesses all the shape characteristics and processing features of a part family. If tooling is developed for the composite component, then any part in the family can be processed with the same tooling.

GROUP JIGS, FIXTURES AND TOOLING SET-UPS

To get the maximum utilization from tooling set-ups, tooling for the operations within a part family should be arranged so that all the parts, or as many as possible, in a family can be processed with one group type fixture and/or one set-up. Group jigs and fixtures are designed to accept every member of the family. An example of such a group jig for drilling a part family is shown in Fig. 10. To drill the holes of eight (8) different parts in this part family, it requires only one group jig and eight (8) different auxiliary adapters to accommodate some differences in sizes, numbers, and locations of the holes. Therefore, instead of designing, fabricating, and using eight indivi-

(a) Complicated work-flow system with functional layout



(b) Simple work-flow system with group layout

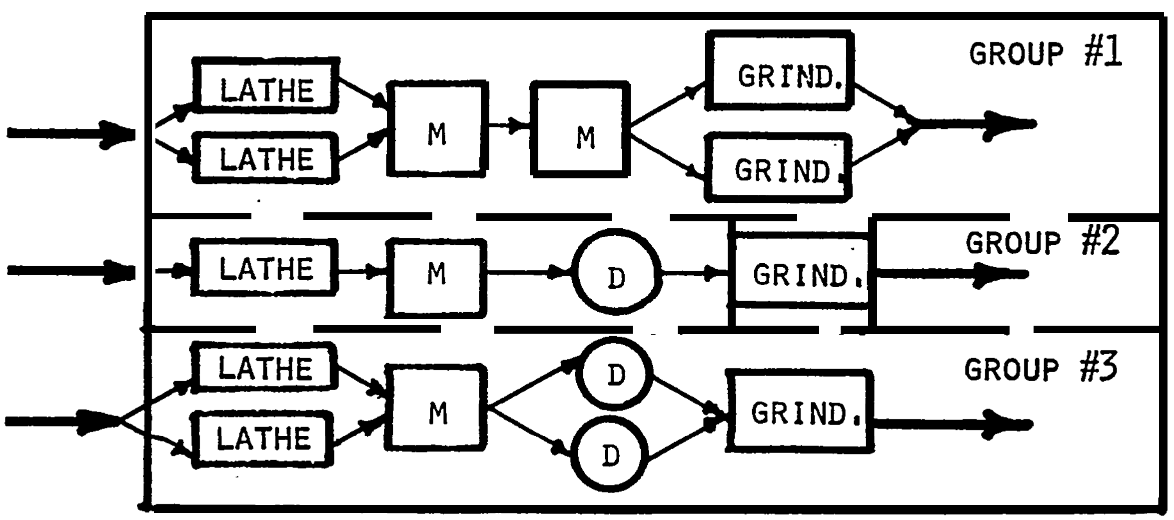


Figure 8, Comparison of functional and qroup layouts of machines: D = drill press, M = milling **Machine**

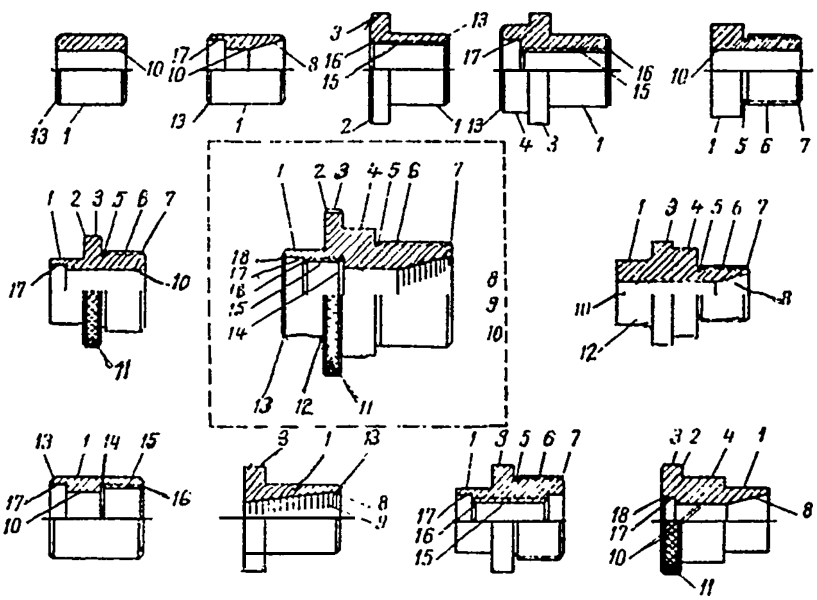


Figure 9, Example of typical composite part

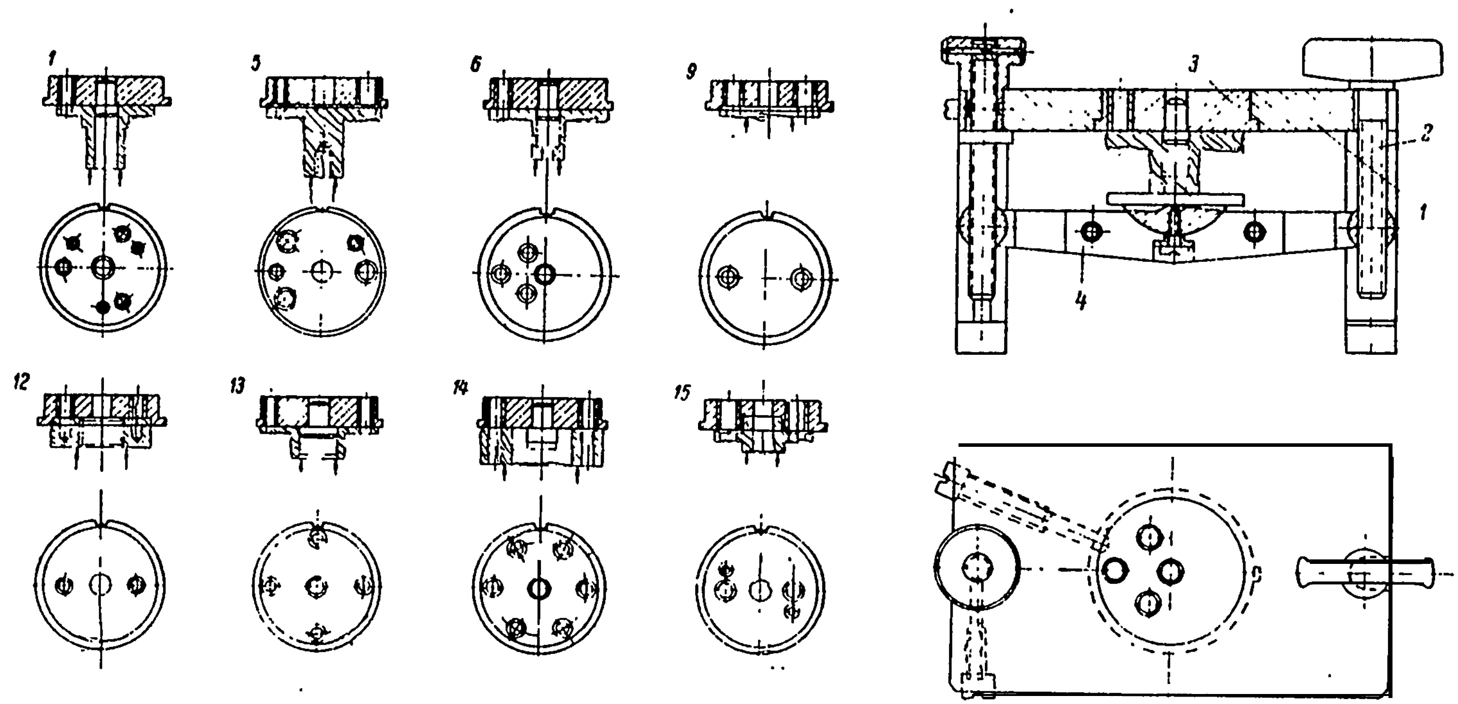


Figure 10, Example of a group drill jig and adapters used for drilling 8 different parts in a part family

dual drill jigs as is done in a conventional production method, only one group jig and eight (8) adapters are required for the same jobs. It becomes clearly evident how much tooling costs can be reduced using Group Technology.

NC PART FAMILY PROGRAMMING

One of the important applications of Group Technology is software development for NC machining. This is referred to as "Part-family Programming" (15). Part-family programming is an NC program system that groups common or similar program elements into a single, master computer program. The master computer program, or pre-processor, is a permanent base from which an NC tape can be prepared for any part in the part-family. Therefore, part-family programming increases the productivity of costly NC operations by saving programming time, manpower, and tape prove-out time. It also reduces lead time, tool inventory, and simplifies maintenance and requires fewer computer reruns.

COMPUTER AIDED PROCESS PLANNING

One of the essential requirements for the implementation of CAD/CAM is computer aided process planning. The use of an automated process planning technique is a basis for a rational and logical approach to improve manufacturing productivity in a CAD/CAM system.

It has been recognized that Group Technology is an essential element for the successful execution of computer automated process planning. As indicated in the flow diagram proposed by CAM-I (Fig. 11), the logical approach to successful automated process planning is a system based on the part family concept of Group Technology. The development of part families, using suitable classification and coding systems, will make it possible to systematically form part families and thus rationalize and develop standards of shape and process within the part families, making it possible for the automatic generation of process plans.

FLOW DIAGRAM

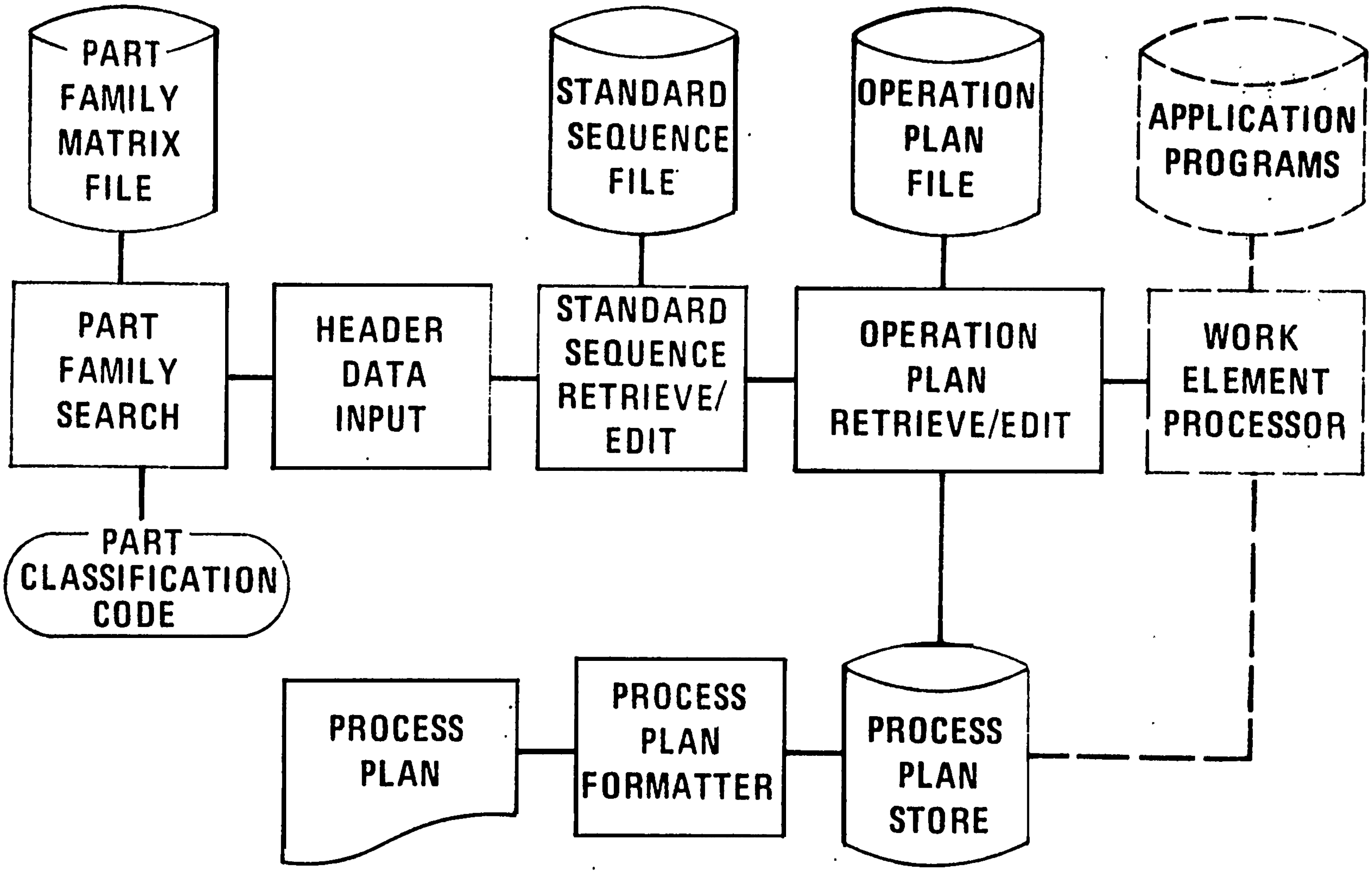


Figure 11, Flow diagram for computer aided process planning by CAM- I (8)

PRODUCTION CONTROL AND SCHEDULING

Production scheduling is greatly simplified by Group Technology. The scope of the problem is reduced from that of a large portion of the shop to a small group of machines. If the families of parts and groups of machines have been formed correctly, each job will indicate by its code number which group of machines will process it. Within the group of machines the scheduling problem is again reduced to simply scheduling the given jobs through the machines in a cell. A computer program can be set up to schedule jobs of a part family to a corresponding machine group/cells. The jobs can be properly sequenced in the family and the families properly sequenced through the machine groups/cells.

Proper scheduling is an integral part of Group Technology. When combined with reduced set-up time and reduced transportation, two significant cost reduction benefits can be effected. The most obvious benefit is reduction of total production time. With reduction of production time, inventories can be reduced substantially and production work can proceed on schedule. At the same time, scheduling becomes reliable to guarantee the delivery date with greater assurance. Let us call production scheduling associated with G.T. applications "Group Scheduling" (16). Proper application of Group Technology will result in:

a) Reduction of set-up times and costs.
b) Optimal decision of group and job sequences.
c) Possibility of flow-line production.
d) Optimum group layout.
e) Over-all economic advantages.

As uses of computers have become more popular in various manufacturing activities, one of the most successful innovations in the area of manufacturing inventory management is embodied in what has become known as Material Requirements planning (MRP) Systems (17). Since Group Technology applications directly relate to and influence various planning and inventory activities, it is important to consider the interrelationships between group scheduling and MRP. There are already several companies who have successfully implemented both G.T. and MRP in production applications.

ADMINISTRATIVE PROBLEMS

a) PERSONNEL PROBLEMS

In group production methods when a job is assigned to a machine group/cell, it is processed under-given production operations by that one group. The flow of production information into or out of the shop

becomes both easier and more accurate with the group production method. Since all the jobs in a group are confined to a relatively small area of the shop and a small group of men, the group supervisor can have immediate knowledge of the state of completion of all the jobs in the group.

b) SOCIAL PROBLEMS

As Group Technology has become more accepted, it has also become apparent that efficiencies obtained through Group Technology applications are not determined entirely by its technical characteristics. Additional factors of a social nature are making an important contribution, and these are among the major appeals which Group Technology is making to behavioral scientists (18). It offers some solutions to job satisfaction such as worker involvement in decision-making, personalized work relationships, variety in tasks, freedom to determine methods, group production methods, etc.

MANAGEMENT PROBLEMS FOR G.T. IMPLEMENTATION

Installation of the system calls for a high degree of cooperation between a number of groups or departments in the firm. Personnel in design engineering, planning controls, tooling, and the production shop itself must realize how dependent each group is on the others. This level of communication and cooperation is often lacking. It is absolutely essential if Group Technology is to be implemented successfully.

It is a common phenomenon that a great deal of suspicion follows any form of change to an existing pattern of life, whether this change is within an industrial environment or entirely outside of it. Group Technology will not only change the pattern of work environment for many of the employees in a company, but it will also demand a new form of thinking. For successful implementation of Group Technology, the cooperation of everyone concerned is essential. It is recommended that an ad-hoc committee be formed to plan the company-wide G.T. implementation. This committee should be headed by a senior executive who can get close coordination between the involved departments.

FUTURE TRENDS OF GROUP TECHNOLOGY

A forecast of the future of production technology advancement, carried out by both the University of Michigan (19) and the International Institute for Production Engineering Research (CIRP) (20), strongly indicated that the computer automated factory would be a full-blown reality well before the end of this century. It is especially interesting to note that the survey by the University of Michigan researchers predicts that by 1988 more than 50% of industry will use Group Technology in manufacture, while the survey by CIRP indicates that by 1990 70% of industry will use Group Technology in manufacture. It is evident that new technological innovations, such as DNC, CNC, machining centers, industrial robots, micro-processors, etc., will be continuously introduced toward more automated computer integrated manufacturing systems involving CAD/CAM, and thus lead to more integrated applications of Group Technology for optimum manufacturing and higher productivity. The recent effort by a USAF I-CAM project is a positive approach to achieve those objectives (21).

A part classification system, which is an integral part of and has been used as an essential tool of Group Technology applications, can also be evolved as a means of describing parts in a form that can be integrated readily into a computer data base structure which will link design and production. Such a part descriptive classification system identifies and codes basic shape elements such as cylinders, rings, cones, cubes, etc. These basic shape elements are further expanded to include chambers, keyways, threads, and so forth. These shape elements should be selected so that they correspond to groupings of tooling set-ups, machines or machine stations using Group Technology concepts, and also to provide bases for computer automated process planning. Also as evolution of CAD\CAM leads to generative design and to generative process planning, certain part classification and coding systems will become an integral part of the total generative system evolving with CAD\CAM.

Group Technology is a dynamic and revolutionary development which continues to expand its influence on manufacturing systems. It is evident that the role of Group Technology will certainly be broadened with more innovative advancements in theory and application, not only for improving productivity in conventional batch-type manufacturing systems, but also for proper adaptation of CAD/CAM systems.

APPLICATIONS "OF GROUP' TECHNOLOGY

IN SHIPBUILDING INDUSTRY

Two major areas of shipbuilding in which Group Technology application might be considered relevant are:

(1) Component production by group/cell method.
(2) Assembly unit construction.

There are several classification and coding systems designed for sheet metal works (22, 23, 24, 25, 26) and some of them were applied to a ship hull component classification system as an effort for Group Technology implementation in the shipbuilding industry (27).

Some potential benefits of Group Technology applications for the shipbuilding industry are as follows:

(1) Improved production through group/cell production method for cutting, preparation and assembly of steel work.

(2) Design rationalization and improved production planning through effective data retrieval for component size, shapes, variety and production methods.

(3) Rationalization of raw material supply and preparation through standardization and improved inventory control.

(4) Adaptation to computerized automatic process planning and other management information systems.

(5) Variety reduction and standardization of proprietary purchased items.

(6) Rationalization for pipework and pipe fitting and assembly for ship fitting-out process.

(7) Improvement of shipyard organization and layout through group production method.

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THE SFI CODING AND CLASSIFICATION SYSTEM
FOR SHIP INFORMATION

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This paper is about a classification system, or group, account, charge or whatever you call it in your organization. What is different about this system is that it was developed by a group of shipbuilders and shipping companies under the leadership of their national, non-profit research association. When completed and field tested, it was adopted by all members of the maritime community, both public and private. This country was Norway.

Today no one in Norway uses any other system for ship breakdown. In addition, the system is gathering a worldwide following.

The system is called the SFI Group System.

The SFI Group System is a classification system for ship technical and cost information.

During the life cycle of a ship - from conceptual design through detailed design and construction to operation and maintenance - much information must be exchanged

within an organization and between organizations. During the sixties, Norwegian shipbuilding was booming. In addition, electronic data processing had come into its own. Naval architects, shipbuilders, ship owners, regulatory bodies and marine suppliers were looking for a common ground for specification indexing, drawing, numbering and cost accounting.

The Norwegian shipbuilders took the lead, primarily because they were subcontracting to each other, and asked their national research association to sponsor an effort to develop a common ship breakdown system. The SFI Group System was, thus, sponsored by the Ship Research Institute of Norway.

The system was developed primarily by shipyards. It was correctly assumed to be difficult enough to create unanimity among the yards without involving other parties. Several yards provided representatives to help in the development of the SFI Group System lending expertise in estimating, engineering, planning, purchasing, production and EDP. The shipyard representatives were from a broad spectrum of the industry with experience in building ships of all types and sizes. Among the major contributors was the Aker Group - with which my firm is proud to be associated - and which brought the world numerically controlled burning and computer-aided lofting.

During the development phase, ship owners provided input to the working committee and were, in fact, the first to test the system as a maintenance code on board different types of ships - from cargo liners to North Sea trawlers. The experience gained from ship owners was very valuable.

The SFI Group System development was completed and tested in a pilot yard in 1972. The test not only checked the comprehensiveness of the system but provided an

opportunity to analyze routines associated with the use of the system. As might be expected, the routines and procedures in any particular shipyard might not accommodate a given system and it was important to check the system's flexibility.

At the end of the test period, minor changes were made and the SFI Group System was adopted by the Norwegian maritime community. Each user has a contact who stays in touch with the Ship Research Institute concerning changes in ship technology that might affect the system. The Norwegian Ship Research Institute, or NSFI, maintains and revises the system as necessary to accommodate new technology.

The basic criteria for designing the SFI Group System were:

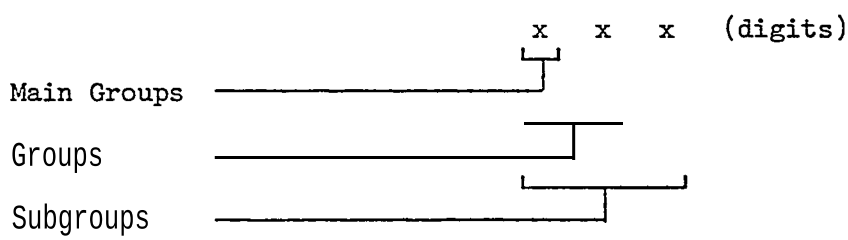
1. that it must be applicable to all users
2. that it must be applicable to all types of ships
3. that it must be simple and easy to understand
4. that it must be capable of future expansion.

As shipbuilders had first crack at designing the system, the immediate argument that had to be resolved was whether the system was to be function oriented or Production oriented. This argument, although interesting, is moot. Production methods change within a shipyard and certainly are different from shipyard to shipyard. Engineering and estimating simply cannot accommodate a production-oriented ship breakdown system whereas production can accommodate a function-oriented ship breakdown.

The SFI Group System is, thus, a function-oriented system. Classification societies, ship owners and naval architects would be lost with a production-oriented system.

In fact, it is rigorously functionally oriented. Components as well as piping are found under the same account number for a given ship's system. Electric motors for pumps are not segregated but are grouped with the driven component. The SFI Group System is designed to conform to a logical ship's specification, to accurately collect direct costs during the design, planning and production phases, and to organize the return costs in a way that they can easily be used as a basis for estimating the cost of similar ships in the future.

The SFI Group System is built up as a three-digit decimal classification system with ten main groups at the highest level. At this time only eight main groups are in use. Each of the main groups (one digit numbers) consist of ten groups (two digit numbers) and each group is further subdivided into ten subgroups (three digit numbers). Hence, the structure of the Group System numbers is as follows:



The main groups are used as follows:

0:

Reserved for a special purpose.

1: Ship General

Includes costs which cannot be charged to any specific function on board, such as launching, trial trips, guarantee work.

2: Hull

Includes hull and superstructure as well as cleaning and painting of the ship.

3: Equipment for Cargo

Includes equipment and systems concerning the ship's cargo, such as hatches, cargo winches, cargo pumps and piping.

4: Ship Equipment

Comprises equipment and systems which normally are peculiar to ships, such as navigation equipment, anchoring equipment. It also includes fishing equipment and weapon systems along with other working equipment for special types of ships.

5: Equipment for Crew and Passengers

Includes equipment and systems which serve crew and passengers, such as furniture, elevators, hotel systems.

6: Machinery Main Components

Comprises the primary components in the engine room, such as main engine, boilers, auxiliary engines.

7: Systems for Machinery Main Components

Includes main propulsion systems, such as fuel and lube oil systems, starting air system, exhaust systems.

8: Ship Systems

Comprises auxiliary systems, such as bilge and ballast systems, fire fighting and wash down systems, electrical distribution systems.

9:

Reserved for a special purpose.

As an example, the freezing system for dry cargo would be derived from:

Main Group 3 : Equipment for Cargo

Group 36 : Freezing, Refrigerating and Heating Systems for Cargo

Subgroup 362: Freezing and Refrigerating Systems for Dry Cargo

Illustrations of how this is presented in the SFI Group System book are:

the main group **3** matrix (see Figure 1)

the subgroup 362 description (see Figure 2)

Note that the description of each subgroup shows what that subgroup does not include as well as what it does include.

The SFI Group System book contains several parts. There is a six-page guide to use of the system follcwed by a matrix showing the 100 possible two-digit groups. This is followed by a chapter for each main group. These chapters begin with a

MAIN GROUP 3 – EQUIPMENT FOR CARGO

	35 LOADING AND DISCHARGING SYSTEMS FOR LIQUID CARGO.	36 FREEZING, RE-FRIGERATING AND HEATING SYSTEMS FOR CARGO.	37 GAS/VENTILA-TION SYSTEMS FOR CARGO HOLDS/TANKS.	38 AUXILIARY SYSTEMS AND EQUIPMENT FOR CARGO.	39
	350	360	370	380	390
	351 Loading and discharging pumps.	361 Insulation and sheathing of cargo holds and tanks.	371 Ventilation systems for refrigerated cargo holds.	381 Sounding. control and operating equipment for cargo systems.	391
	352 Loading and discharging systems on deck	362 Freezing and refrigerating systems for dry cargo.	372 closed Cycle mechanical ventilation systems for cargo holds.	382 Tank cleaning systems and equipment.	392
	Loading and dis-charging systems in pump rooms.	363 Direct cooling systems for liquid cargo.	373 Open ventilation systems for cargo holds.	383 Lifting gear for cargo hoses.	393
SUB-GROUPS	Loading and dis-charging systems in cargo tanks.	364 Cascade cooling systems for liquid cargo.	374 Ventilation/gas freeing systems for tanks. Wind sails with equipment.	384 Separate cooling water systems for cargo equipment.	394
	355 Loading and dis-charging systems for LPG, LNG, etc. in gaseous phase.	365 Indirect cooling/ heating systems for cargo (cargo oil heating, etc.).	375 Blow-off systems from safety valves (from pressure/ vecuum valves and similar).	385 insulation drying system for cargo holds and tanks.	395
	356 Separate stripping system.	366	376 Inert gas systems with conditioning plant.	386 Equipment for addition/porti-oning of preserva-tives, smelling substances, inhi-bitors, spirits, etc.	396
	357	367	377 Fuel gas system with conditioning plant.	387 Special structures for loading/dis-charging over sternistem.	397
	358	368	378	388	398
	359	369	379	389	399

SFI GROUP SYSTEM – JAN. 73

PARTIAL MAIN GROUP 3 MATRIX

Figure 1

362 FREEZING AND REFRIGERATING SYSTEMS FOR DRY CARGO

Freezing and refrigerating systems far dry cargo (e.g. fruit, vegetables, meat, etc.) and also for dry cargo and provisions combined, including such as:

Refrigeration machinery with compressors including drive units, condensers, evaporators, cooling batteries, oil separators, driers, etc.
Circulation system (for brine, ammonia, Freon or similar) with circulation pumps, valves, insulation, pipes, etc.
Fans for circulation by/through cooling batteries.
Drip water trays with drain pipes.

Also included here is the refrigeration machinery (which follows the ship) for containers, with connection hoses and associated machinery as stated above, together with refrigeration machinery for plate freezers, for freezing tunnel, for ice production and far RSW plant (Note! see also Ref.) with associated machinery as stated above.

Ref: Containers with separate refrigeration machinery (which follows the container) 317
Insulation of cargo holds and tanks 361
Ventilation plant with ozone generator, etc. for refrigerated cargo holds 371
Arrangement for remote measurement of temperature, CO_2, humidity, etc. 381
Supply lines from separate cooling water system for cargo equipment, **for thawing (de-icing) of refrigeration machinery** 384
RSW plant (seawater part) 384
Plate freezers, freezing tunnel (in factory plant for fish, etc.) 468
Refrigeration machinery for provisions 554
Supply lines from the ship's main cooling water system for thawing (de-icing) of refrigeration machinery, se resp. s.gp in . . . . gp 72
Drain pipes from sink, including those, in cargo holds 804

363 DIRECT COOLING SYSTEMS FOR LIQUID CARGO

Direct cooling systems (one or more stages) for recondensation of gas cargo, where the boil-off is extracted from the tanks, compressed and condensed directly by cooling water. The system includes such as:

Suction pipes from tanks or loading/discharging pipes with valves, etc.
Fluid separators with return pump, piping, etc.
Compressors with drive units (low and high pressure compressors for multi-stage plant), filters, etc.
Medium pressure vessels with equipment (for multi-stage plant).
Fluid collectors.
Cargo condensers.
Return pipes for the condensed cargo to tanks or to the Ioading/discharging system.

Also included here is the arrangement for lubricating the compressors, with equipment for oil regeneration.

The cooling plant, or parts of it, can have subsidiary functions (but comes under this s.gp) and function as:

Pumps for cargo heating.
Producer of gas for transfer of cargo for discharging by means of pressure.
Continues

matrix showing the 100 possible three-digit subgroups within each main group followed by a detailed description of each group and subgroup. Finally, there is an alphabetical index (Figure 3) with more than 4,000 entries that should lead the searcher to the proper subgroup number. For our "freezing and refrigerating system for "dry cargo" example, the most obvious entry appears on page 32 of the index although it appears elsewhere as well.

The books are loose leaf to facilitate changes and are made of all water resistant materials. A condensed, pocket-sized version containing only the main group matrices and index is also available.

For those requiring even further breakdown than the three-digit system provides, NSFI has developed two sets of supplementary codes. Designed primarily for material, the first set is for direct purchased material and must be used in conjunction with the appropriate subgroup (Figure 4). Using our "freezing and refrigerating systems for dry cargo" example, the number 362 003 would always identify the freezing system compressor or compressors. The second, or section 2 detail code, is a listing of stock materials and does not necessarily need to be identified with the appropriate subgroup (Figure 5). Each of the detail codes contains three digits and is published in a supplementary booklet.

With its flexibility and functional orientation, the SFI Group System can be used for any shipyard classification problem. It can, and should, be used consistently in all of the following areas:

1. indexing of specifications
2. drawing identification
3. purchase requisition and order numbering

INDEX

Figure 3

Gr. 36 FRYSE-, KJOLE- OG VARMESYSTEM FOR LAST

U.gr. 361 ISOLASJON OG KLEDNING AV LASTEROM/-TANKER 361

361060
361061
361082
361083
361084
361085
361086
361087
361088
361089

U.gr. 362 FRYSE-/KJ0LESYSTEM FOR T0RRLAST 362

362 001	KJoleaggregat, kuldemedium..	**Cooling agg. cooling medium**
362 003	Kjolekompressor m/drivenhet	Cooling compressor
362 005	Kondenser	**Condenser**
362 007	Vaeskesamler	Liquid receiver
362 009	Fordamper	Evaporator
362 011	Vaeskeutskiller	Liquid separator
362 013	Torkefilter	Drying filter
362 015	Sugefilter	Suction filter
362 017	Oljeutskiller	Oilseparator
362 019	Sirk.pumpe, kuldemedium	Circulatlonpump. cooling med.
362 021	Fyllepumpe, kuldemedium	Supplypump. cooling med.
362 023	Kuldemediumtank	Tank for cooling medium
262025	Lokalt kontrollpanel	Local controlpanel
362 030	Lakekjoler	Brinecooler
362 032	**Lakeforvarmer . . . .**	Brinepreheater
362 034	Blandetank	Mixingtank
362 036	Sirk. pumpe. lake	Circulationpump, brine
362 038	Fyllepumpe, lake	Supplypump, brine
362 040	Laketank	Brinetank
362042	Kjolebatterier	Cooling batteries
362044	Sirkulasjonsvifte	Circulation fan
362070	Smoreoljesystem, compressor	Lub.oil system, compressor
362071	Smoreoljepumpe	Lub.oil pump
352073	Smoreoljefilter	Lub.oil filter
362075	Smoreoljeseparator	Lub.oil separator
362077	Smoreoljekjoler	Lub.oil cooler
362079	Smoreoljetank	Lub.oil tank

362080
362081
362082
362083
362084
362 085
362086
362097
362088
362089

Kjøpte timer, leide timer, kjøpt ass., patentutg. etc. se Brukerorient.

DETAIL CODE, SECTION 1

Figure 4

CL. 21 INSULATION AND PACKING MATERIALS.

S.cl. 210 General.
211 Insulation and fire proof materials (excl. pipe insulating materials.
212 Pipe insulation materials.
213
214 Plate and box packings, cord and strip packings incl., packing material.
215 Flange packing rings, manhole and inspection hatch packing-rings.
216 Moulded packings, packings for special applications.
217 Sealing and O-rings.
218 Lip packings, U-packings, CUP and dome Packings. incl., sealing rings for rotating axles.
219 Diverse.

CL. 22 PIPES AND HOSES INCL, PARTS FOR PLATE AND CAST IRON PIPES.

S.cl. 220 General.
221 Steel pipes.
222 Non ferreous metal pipes.
223 plastic pipes and plastic hoses.
224 Other hoses and flexible pipes.
225 Plate pipes and associated parts.
226 Cast iron pipes and associated parts.
227 Discharge pipes and associated parts (sail pipes).
228
229 Diverse.

CL. 23 COMPONENTS FOR PLASTIC PIPES AND HOSES.

s cl. 230 Generel.
231 Polyethylene components.
232 Styrene components (synthetic rubber).
233 Nylon based components.
234 P.V.C. components.
235
236
237 Pipe components for plastic pipes with coupling, decoupling arrangements.
238 Hose clamps and junctions (not fire fittings/equipment).
239

CL 24 PIPE COMPONENTS FOR STEEL AND METAL PIPES. (Excl. plate and cast iron pipes).

s cl. 240 General
241 Components for steel threaded pipes, Black steel.
242 Components for steel threaded pipes. Steam.
243 Components for steel threaded pipes Gelvanized.
244
245 Components for brass threaded pipes.
246 Couplings etc., components far smooth (seamless) pipes.
247 Bends, Hanges. etc., components for smooth (seamless) pipes
248 Unions. bulkhead flanges, deck penetrations etc.
249 Diverse

DETAIL CODE, SECT ION 2

Figure 5

4. work package identification
5. labor and material cost collection
6. test agenda identification
7. technical manual identification
8. recommended spare parts list identification
9. estimating
10. guarantee work identification
11. general filing index.

After several years of use, the information retrieval capabilities of the shipyard are greatly enhanced.

Now, carry the application of the SFI Group System one step further as the Norwegians have done. Have all shipyards, naval architects, marine suppliers, the ABS, MarAd, the Navy and ship owners use the same system. Communications become easy. Specifications for new construction, repair, material and subcontracting are more consistent in format. Design and testing criteria for each system can readily located. Cost and progress reporting do not need to be translated from one account system to another. Duplicate sets of financial books are eliminated. It is even possible that shipyard qualification to DOD Instruction 7000.2 can become understandable with a common frame of reference.

Is standardization possible? Norway has a far larger merchant fleet and an equivalent number of shipyards as the U.S. The answer, then, probably lies in the willingness of MarAd and the Navy to jointly agree to such a move.

With or without standardization, if your shipyard doesn't have a functionally-oriented classification system similar to the SFI Group System, it should have. And if your system isn't as good as the SFI Group System, it should be. The advantages of a well-designed classification system are too obvious.

HOW SMALLER SHIPYARDS ARE PROFITTING THROUGH N/C

Doald P. Ross
Cali and Associates, Inc.
Metairie, Louisiana

Mr. Ross is Manager of N/C Lofting Service Activities. He has twenty years' experience in shipbuilding ranging from production to engineering supervision and management. Since 1969 he has worked in the area of N/C lofting.

INTRODUCTION

Since its introduction to U.S. shipbuilding some ten years ago, N/C Lofting and plate cutting has been regarded by most as a production tool for the larger shipyards only.

This presentation is intended to dispel those thoughts by deomonstating active usage of N/C Lofting by the smaller shipyards as a tool to increase production efficiency and reduce costs.

How Smaller Shipyards Are Profiting Through N/C

In this presentation, we will discuss the use of N/C Lofting by the following shipyards and boatbuilders:

Atlantic Marine, Inc.
Kings Craft Corp.
Marinette Marine Corp.
McDermott Shipyards
Peterson Builders, Inc.
Service Machine & Shipbuilding Co.
Steiner Shipyard
Tacoma Boatbuilding Co. , Inc.
Toche Enterprises

This is by no means a complete list of shipyards and boatbuilders currently using N/C lofting and cutting in production, but represents those with which we are more familiar through service contracts with them.

ATLANTIC MARINE, INC.

Atlantic Marine, Inc. has had one vessel, a 65-foot stock trawler, faired by N/C. They recently sub-contracted the fairing and N/C Lofting of a 79-foot trawler with the steel to be cut at Avondale Shipyards, Inc. , and shipped to their facility. Scheduled completion of the lofting is July 15, 1977.

At present, Atlantic Marine, Inc. is considering the purchase of an N/C burning machine to serve their production needs, as well as cutting for other fabricators.

KINGS CRAFT CORP.

Kings Craft Corporation sub - contracted the fairing and partial N/C lofting of an all aluminum 75-foot home cruiser last year. The material for this vessel was cut by Reynolds Aluminum supply Company in Birmingham, Alabama on their N/C controlled plasma cutting machine.

MARINETTE MARINE CORP.

Marinette Marine Corporation has been actively engaged in N/C plate cutting since 1972. To date, they have completed, or have under construction, the following N/C lofted vessels:

150 Ft. 'ARTUBAR' Tugs
225 Ft. Fleet Tugs,T-AFT
34 Ft. Mini-ATC’s
56 Ft. LCM6'S
136 Ft. LCU's
109 Ft. YTB’s
65 Ft. PB’s

McDERMOTT SHIPYARDS

McDermott Shipyards, Morgan City Division, installed an .N/C cutting machine in 1973. To date, they have completed or have under construction the following N/C lofted vessels: 126-foot tug for Robin Towing Corp. , 136-foot tug for Crowley, 175-foot catamaran tug for McDermott, 126-foot tug for Moran, and a 210-foot Supply vessel for Offshore Logistics.

McDermott Shipyards, New Iberia Division, recently subcontracted the N/C fairing and lofting of a 180-foot offshore supply vessel, with the steel to be cut at the Morgan City Division.

PETERSON BUILDERS , INC.

Peterson Builders, Inc. recently made the decision to adopt N/C plate cutting in their yard. They have subcontracted the total N/C lofting of the PGG-1 Class Gunboats to include: all stiffener lengths, end-cut templates, frame bending information, roll sets and shape templates, along with the N/C tapes required to cut the entire vessel. The cutting will be done on a new machine purchased by Peterson Builders, utilizing plasma arc.

SERVICE MACHINE & SHIPBUILDING CO.

subcontracted to Avondale Shipyards, Inc. , where all plate parts from the keel to the pilot house were cut.

STEINER SHIPYARD

Steiner Shipyard recently sub-contracted the N/C lofting and cutting of all the plate parts for a 75-foot stock trawler. All the plate parts for the vessel from the keel to the pilot house top will be N/C cut at Avondale Shipyards, Inc. Current projections call for cutting of two vessels at a time, with ten or more total to be cut over a period of about ten weeks.

TACOMA BOAT BUILDING CO., INC.

Tacoma Boatbuilding Co., Inc. purchased an N/C cutting machine with plasma are capabilitiess in the fall of 1976. They have since sub-contracted the total N/C lofting of the SWOB -1 Class Sewage Waste Offloading Barges for the U.S. Navy, and the 140-foot WYTM Cutter for the U.S. Coast Guard. The barge contract is well underway, with several units complete at this time. The WYTM has just recently started production with the cutting of parts for the first module.

TOCHE ENTERPRISES

Toche Enterprises, a new and expanding shipyard in Mississippi, sub-contracted the N/C lofting and cutting of all plate parts for two (2) 121-foot oceangoing tug boats. The steel for these vessels was cut at Avondale Shipyards, Inc. and shipped by truck to the Toche facility where it was sub-assembled and erected. The first of these vessels is completed, and the second is scheduled for launching shortly.

CONCLUSION

In discussing their experience of fitting parts that have been lofted and cut by N/C, each of the yards concluded that there had been a definite improvement in the quality of fitting, and a subsequent reduction of man-hours required for that task. Along with the reduction in fitting man-hours, there would also be a reduction of welding man-hours, since the former has a definite influence on the latter.

Actual cost saving figures were not put forth by any of the yards for several reasons; however, some have indicated a total savings on steel construction in the order of ten percent. Our personal opinion is that a savings on the order of twenty per cent of total steel construction is a conservative and reasonable expectation with the use of N/C lofted and cut parts.

The trend today by the smaller yards seems to be toward the use of N/C as a means of reducing costs and thus becoming more competitive. As more N/C burning machines are installed around the country, more yards are placed in a position to take advantage of N/C lofting and cutting and the subsequent cost savings inherent in its application.

COMPUTER AIDED SHIP DESIGN AND CONSTRUCTION IN THE NAVY

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Currently, Mr. Corin is Manager of the Computer Aided Design and Construction (CASDAC) system at DTNSRDC. He has over 40 years' experience in the shipbuilding industry in England and in the United States as apprentice shipbuilder, naval architect and special engineer with Bethlehem Steel Central Technical Department.

Mr. Corin received his training at the University of Durham in England and at the Technical University of Norway.

1. Introduction

The paper discusses a number of facets of Computer-Aided Ship Design and Construction (CASDAC) in which the writer has been involved. A brief history of computers in the Navy is given, some notes on the CASDAC project, the flavor of two recent programs, Navy planning and philosophy in detail design. and construction, some notes on the Computer-Aided Piping Design and Construction (CAPDAC) project, and finally some notes on the increasingly important role of computer science.

The U. S. Navy has a long history in the use of computers in shipbuilding. In May 1944 the first computer came into operation at Harvard, the Automatic Sequence Controlled Calculator -- the Harvard Mark I. This was designed and constructed by Professor Howard Aiken -- at that time a Commander in the United States Navy. It was the Bureau of Ships which first sponsored the operation of this calculator and some of the first problems attacked originated from the Bureau.

In 1952, the Applied Mathematics Laboratory was established at the now David W. Taylor Naval Ship Research and Development Center (DTNSRDC) to initiate computer service to the Navy. For this installation the Univac's 6th computer was installed in 1953. Early work included shaft vibrations, shell stiffening, propeller design, underwater sound intensities, pipe stress analysis, and nuclear reactor design. Within a year, this computer was operating around the clock. By 1958, clients included personnel from the naval shipyards processing programs associated with their ship construction program. By 1960 naval shipyards possessed their own computers and programs were in operation for tank capacity tables, hull deflection, voltage drop, shock mounts, sound isolation, mast calculations, weights and moments, propulsion shaft bearing reactions, pipe bend calculations and pipe stress analysis.

In 1964, the Computer Aided Ship Design and Construction (CASDAC) project was initiated and is now under the sponsorship of the Naval Sea Systems Command (NAVSEA), with *technical* management in the Naval Ship Engineering Center (NAVSEC) and

2. Computer-Aided Ship Design and Construction (CASDAC)

The broad objectives of CASDAC are to employ computers:

(a) to provide improved ships and ship systems at reduced cost, and

(b) to reduce ship acquisition time.

In 1965, a comprehensive program *was* proposed covering the principal areas of ship design and construction. However, Navy priorities of the late 60's and early 70's were such that funding for this program was severely restricted. Work accomplished has been mostly in the area of preliminary design, except for two large detail design programs, Computer-Aided Structural Detailing of Ships (CASDOS) and Cabling and Wiring (WIRES). In preliminary and contract design there are currently about one hundred Navy programs listed in the new edition of CASDAC Computer Abstracts. To give the flavor of some of the work being accomplished, two topics are discussed below -- Integrated Design and Interactive Graphics.

3. Integrated Ship Design System (ISDS)

Attempts to link programs together are well known to result in dilemmas relating to input/output incompatibilities. Of equal importance, when programs are linked across the boundaries of more than one discipline, the resultant suite of programs seems to become an orphan -- people want only to maintain their own portion of the whole. These problems are resolved when, in lieu of linking together, programs are made to operate against a maintained data base. ISDS was conceived as a mechanism whereby time spent on preliminary ship designs could be substantially reduced. The system is under development at DTNSRDC for the Naval Ship Engineering Center (NAVSEC). Figure 1 shows the collection of ship design programs which currently reside in ISDS. Figure 2 outlines the operation of the ISDS.

The principal components of the system are:

- **Ship Design File, which provides a residence for design data pertaining to a specific ship.**

- **Catalog data files -- storage for particulars of equipment common to many ships, e.g., electronic components, deck machinery, etc.**

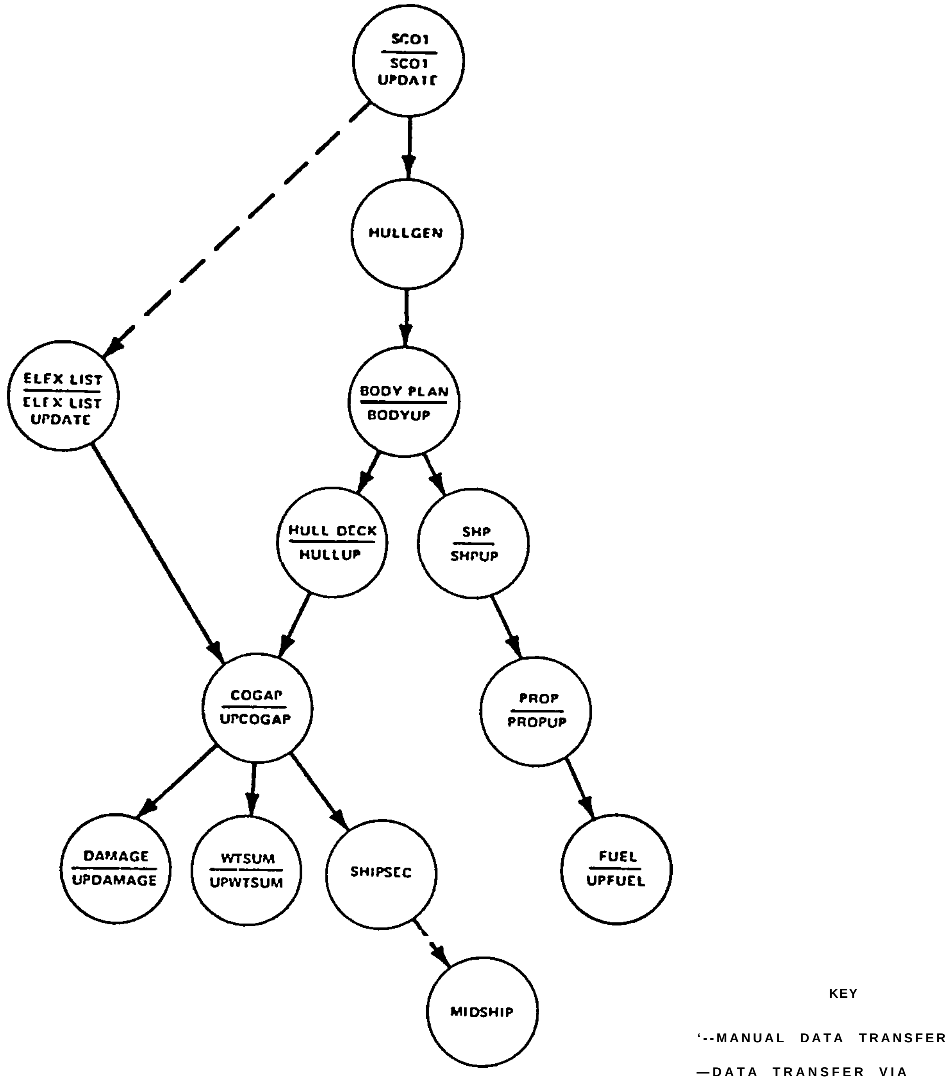


Figure 1 - ISDS DESIGN PROCEDURES

INTEGRATED SHIP DESIGN

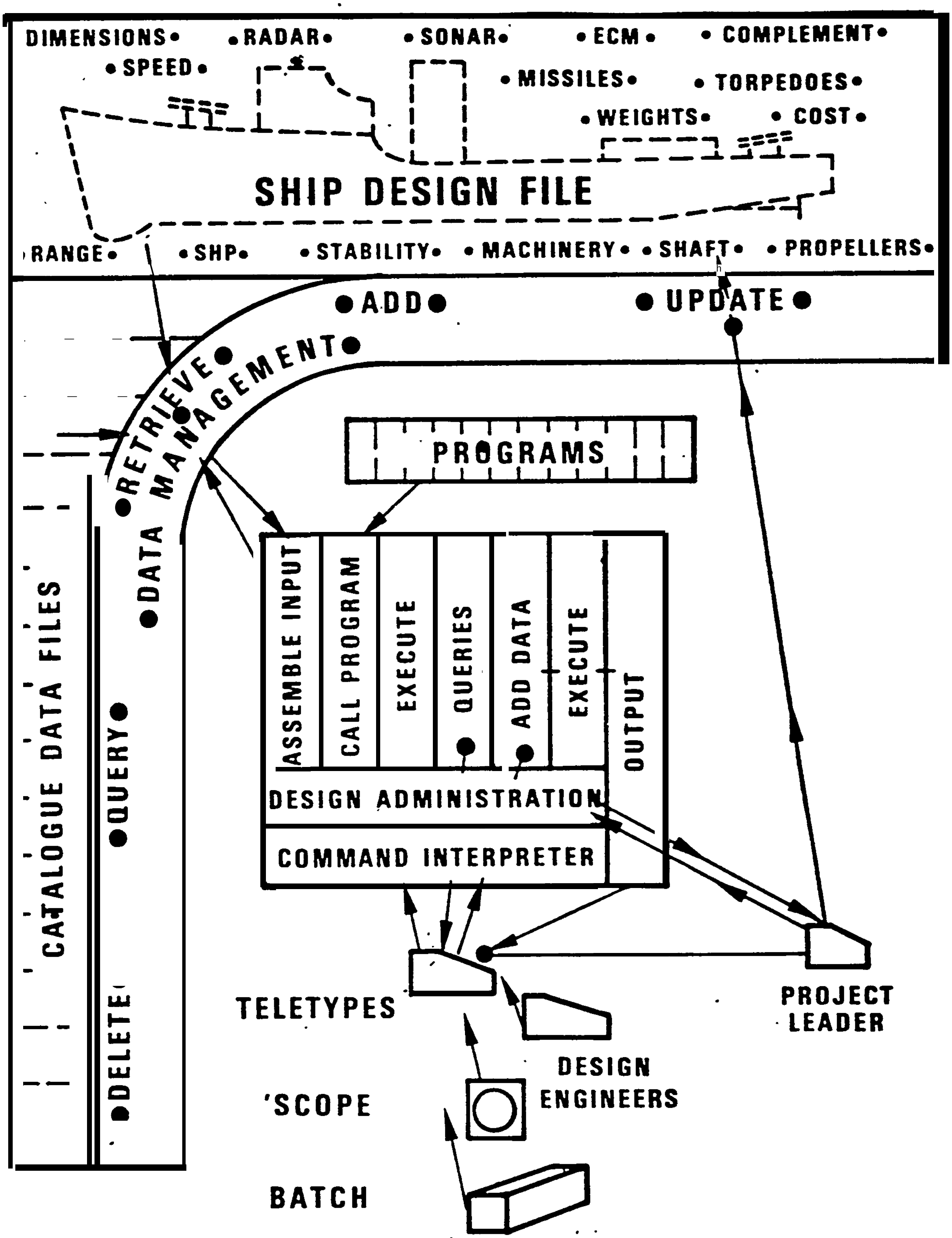


FIGURE 2 - ISDS OPERATIONS

- Ship design programs as shown in Figure 1.

- Central software system, the Computer Aided Design Environment (COMRADE), consisting of an Executive, some Design Administration Procedures, and a Data Management System which can delete, query, retrieve, add, and update data.

The system can operate in the batch mode and interactively from teletypes or a graphics scope. operations are conducted by design engineers under control of a project leader.

For a new design the first program used is a synthesis program, SCO1, which accepts input giving the payload, speed, range, etc. Output comprises particulars for a range of ships, usually of varying lengths. These particulars include beam, draft, depth, coefficients, weights, crew required, etc., all derived from statistical information stored in the program: A ship from this range is selected for detail study and output from SCO1 is used to pollinate the ship design file.

Other programs are called using English language commands, commands are interpreted, and design administration verifies the access rights of the design engineer. Thereafter, the executive assembles input via the data management system from the design file. This may be scrutinized by the design engineer and modified prior to execution. The design engineer may run the program a number of times with varying inputs and the outputs may be saved on a working file. After consultation with the project leader, an acceptable set of results is updated into the ship design file.

The execution of a number of ISDS programs results in the completion of the design file which initially contained only a sparse amount of data from the initial program SCO1.

Most programs are interactive and the user is assisted with two levels of tutorials -- either complete tutorials for the novice or abbreviated tutorials for the expert.

ISDS is currently in a skeletal form with 12 operational programs. The system is now undergoing test and evaluation at NAVSEC. A complete ISDS would include some 30 - 35 programs. While the ISDS represents a substantial advance over a collection of independent programs, ISDS operations do require engineers with more than minimal computer expertise.

4. Interactive Graphics

Work in this area has been maintained at various levels since 1966, first at the CDC Digigraphics Laboratory, later with Navy IBM 1130-2250 equipment, and, currently, with a time-shared CDC 6000 and four CDC 274 scopes with 1700 drivers. Production graphics tasks are marginally satisfactory due to delays at the time-shared mainframe. Local graphics using a minicomputer has been under procurement for the past three years and eventually this will replace the current equipment. Nevertheless, graphics is establishing its place. and two programs may be noted.

A. Hull Generation (HULLGEN)

This program runs within ISDS and also stand-alone. Inputs are ship dimensions, coefficients, an area curve, LCB, load waterline curve and LCF and a *curve* of the flat of bottom. These can be displayed, Figure 3, and may be interactively modified to suit the user. A light pen pick will produce *a* display of transverse station shapes, Figure 4, compatible with the input data. The transverse station shapes may be modified by adding slope specifications at the flat of bottom, the load waterline and at the deck-at-edge. This program enables the designer to review a large number of hull form alternatives during early design.

B. Graphics Arrangements

Segments of this program run within ISDS and other segments currently run stand-alone. Some inputs may be derived from ISDS and others are entered by the user at the scope. The hull and superstructure geometry is stored and may be displayed in the form of plan views and longitudinal and transverse sections. Bulkheads and partitions may be interactively added, thus defining compartments, Figure 5. A substantial capability is being built up to deal with equipment arrangements. Equipment outlines are stored in catalogs as crude or primitive outline approximations. These primitives may be displayed readily and manipulated until an acceptable arrangement is achieved. Upon requesting hard copy, the program accesses detail equipment outlines in lieu of primitives, and the former are plotted for the finished arrangement such as Figure 6. Some 1000 pieces of equipment are incorporated in the catalogs.

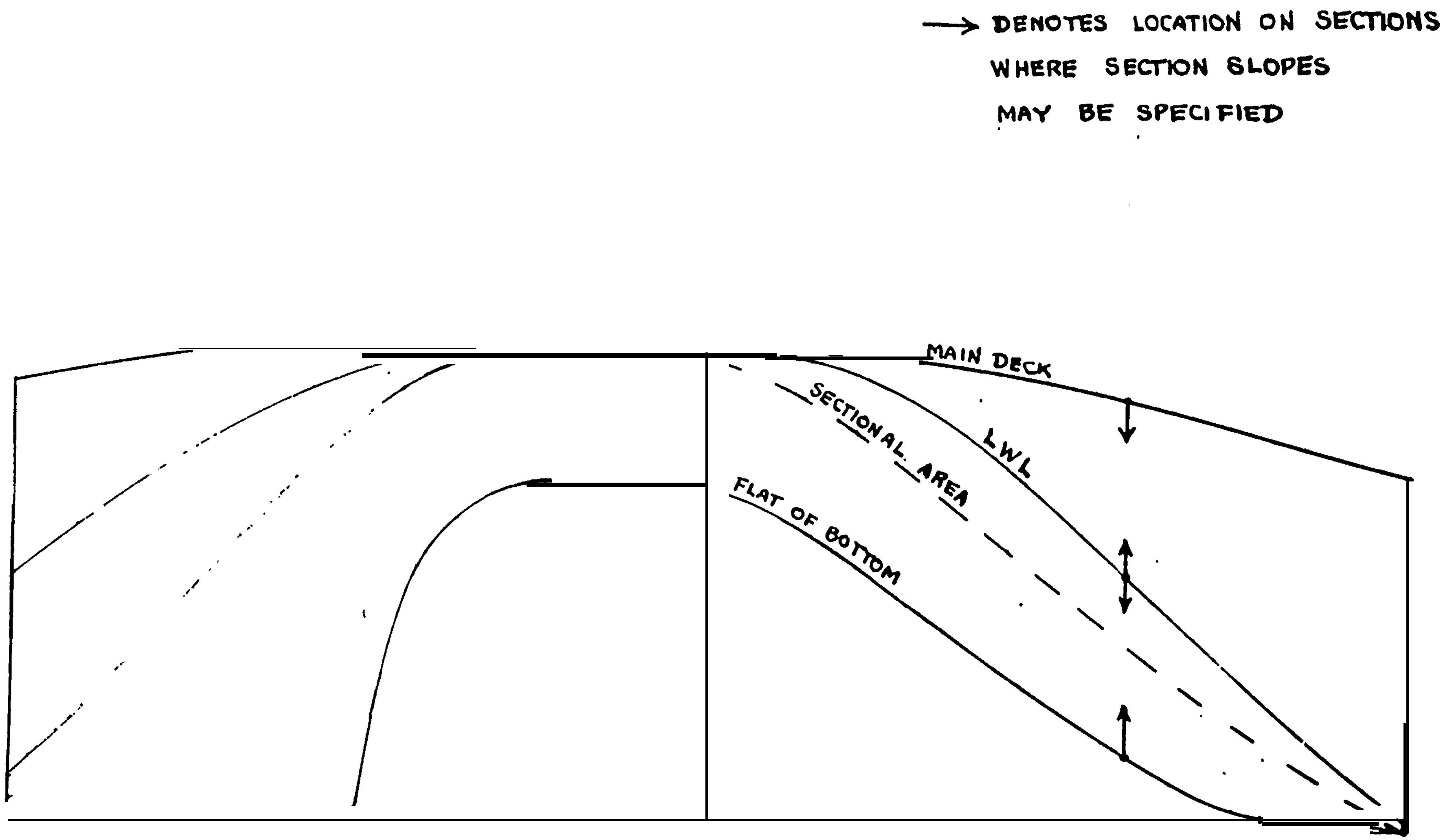


FIGURE 3 - HULLGEN INPUT DISPLAYS

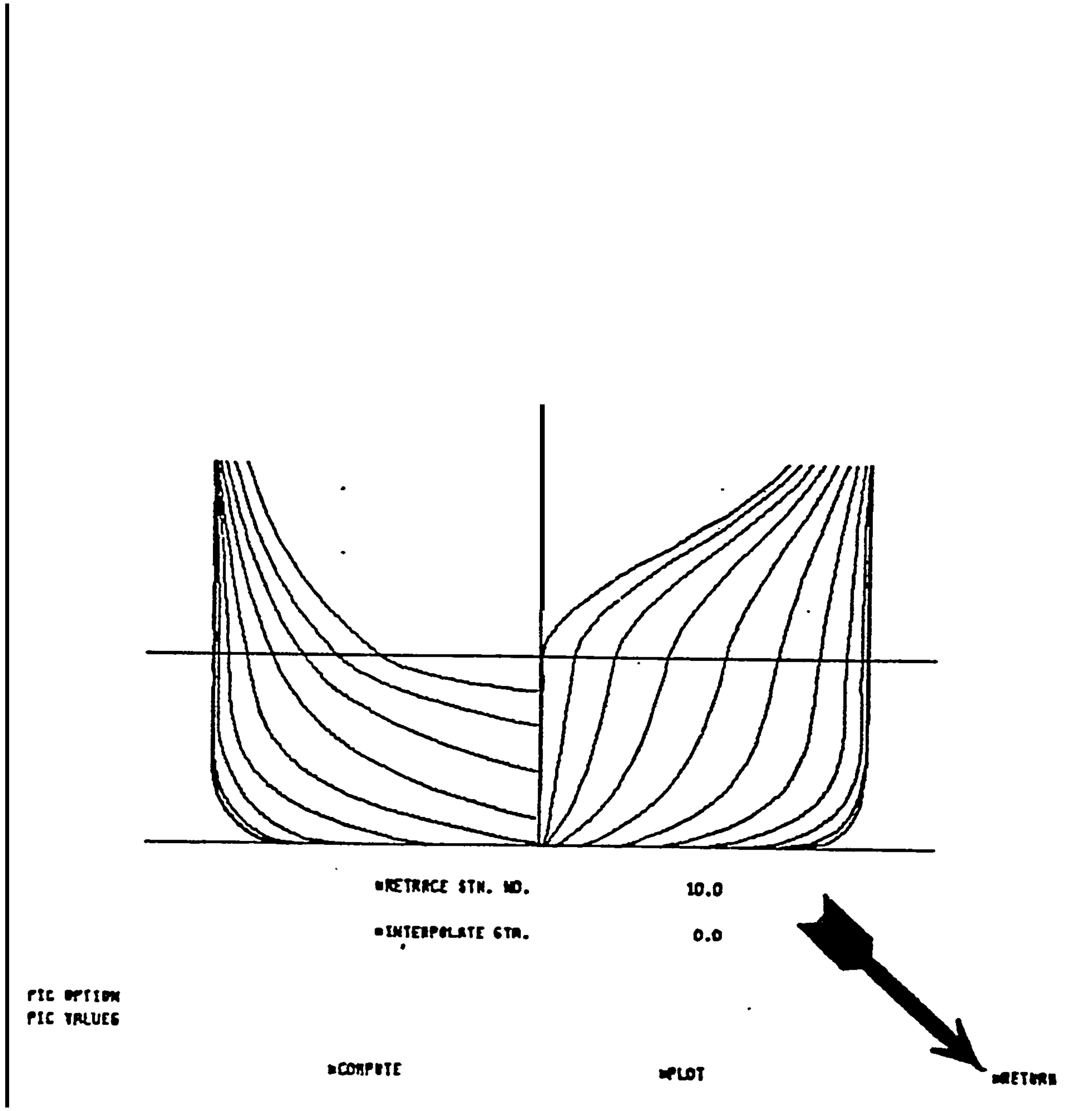


FIGURE.4 - HULLGEN BODY PLAN DISPLAY

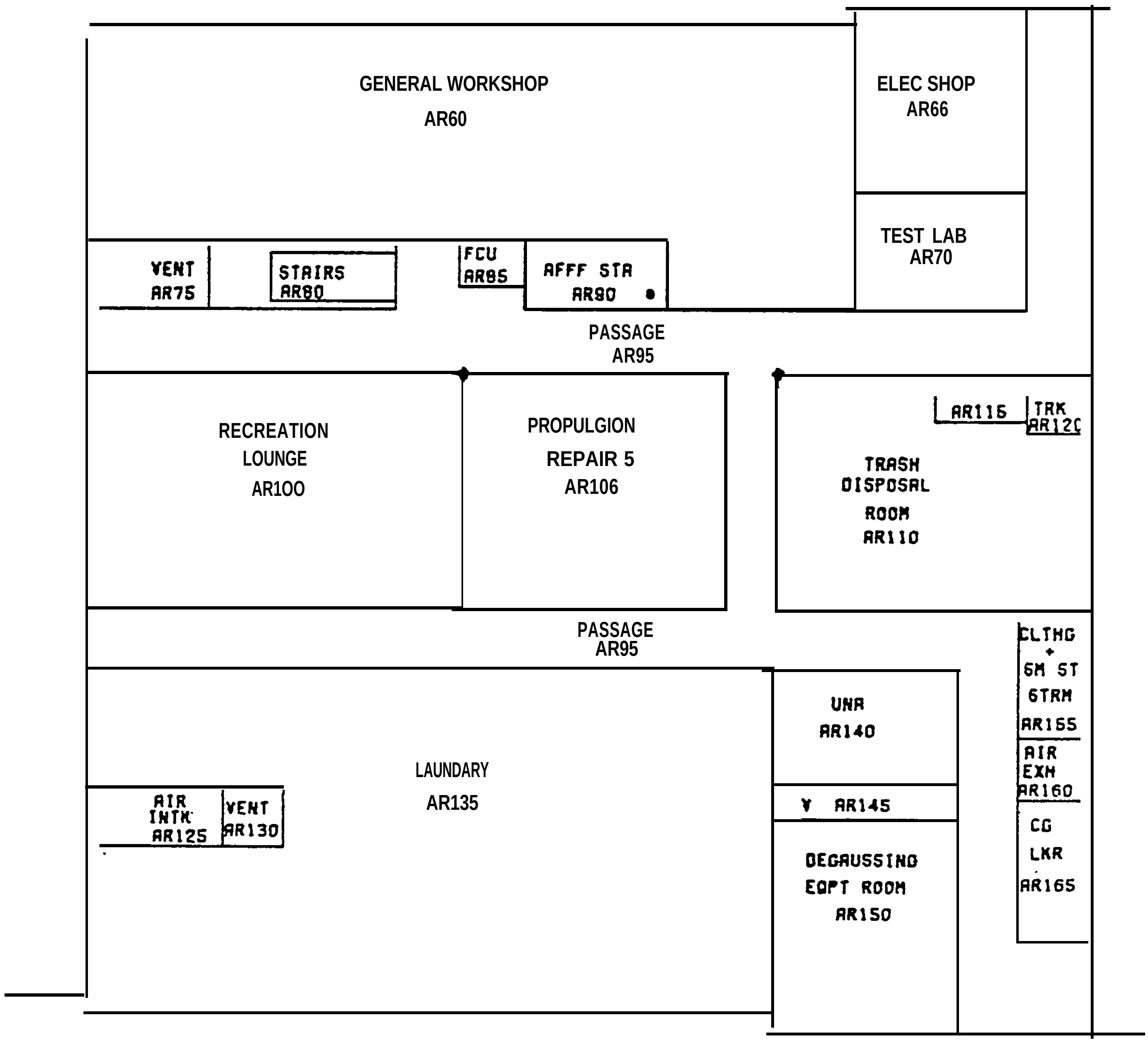


FIGURE 5 - GRAPHICS ARRANGEMENTS - COMPARTMENTS

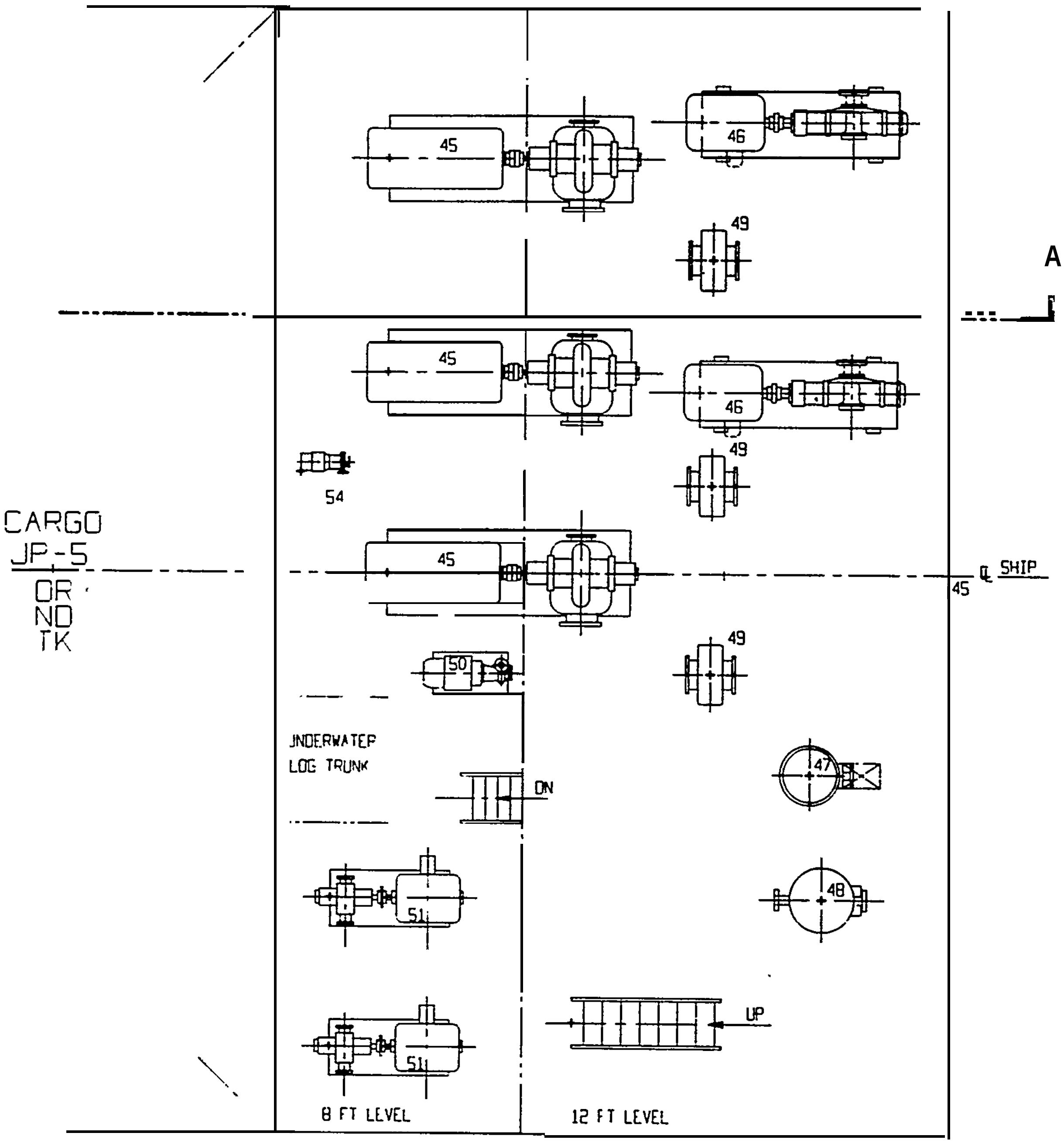


FIGURE 6- GRAPHICS ARRANGEMENTS - EQUIPMENT

5. Detail Design and Construction Plans

The introduction of a Manufacturing Technology program by the Department of Defense in the mid-70's saw improved prospects of fiscal support for work in detail design and construction. Development philosophy was initiated and a number of guidelines was developed:

(a) User involvement was essential to planning programs, establishing their development priorities and execution of test and evaluation.

(b) While integrated system could be a long-range goal, programs should be developed for initial stand-alone operation and integration potential built in, if possible. When feasible, new programs should be compatible with and complement software currently in production use by shipyards.

(c) The earliest implementation was to be given to those programs which could produce highest dollar and/or time savings.

(d) Useful existing programs should be recognized, and acquired when suitable and adaptable.

(e) Inasmuch as the majority of Industry uses IBM computers, IBM program versions would always be developed and maintained. CDC, Honeywell and Univac versions would be implemented depending on the extent of the demand.

(f) To facilitate program portability between computers of various manufacture, programs would be constructed in modular form and have complete documentation.

(g) Application program development would generally be under prime contract with shipbuilders or shipbuilding design agents. Contractors would be asked to report program performances in the construction environment.

(h) Particular attention was to be accorded the interface between programs used in Contract Design (Level III) and programs developed for Detail Design (Level IV) and Construction (Level V).

(i) Development would generally address technical programs and data and exclude management information systems - although technical input to the latter might be developed.

Again, for convenience in planning, detail design and construction was subdivided into a hierarchy with the following components:

Functional Systems:
- Hull
- Handling (boats, mooring, stores, ammunition, etc.)
- Machinery
- Piping
- Heating, Ventilation and Air Conditioning (HVAC)
- Electrical/Electronics

Subsystems:
Each functional system would contain a number of subsystems.

Programs:
Each subsystem would contain a number of programs.

Modules:
Each program would contain one or more modules.

Algorithms:
Each module would perform a single function and would consist of one or more algorithms. Each algorithm consists of one or more source code statements.

The hierarchy described above admits systematization and, while this is a long-term goal, nothing prohibits the development of stand-alone programs of high savings potential.

Again, programs are not necessarily unique to particular subsystems. It can be anticipated that arrangements, drawing, document generating and other programs might well serve a number of subsystems.

The orderly development of programs for CASDAC has been the subject of considerable discussion. It is planned that Documentation will follow the Department of Defense Manual 4120.17M as implemented for the Department of the Navy by SECNAVINST 5233.1A - Automated Data System Documentation Standards. Briefly, for programs, the following documents will be required:

Program Functional Description
Program Specification
Test and Implementation Plan
Test Report
Users' Manual
Computer Operations Manual
Program Maintenance Manual

The first three documents will be required before coding is begun and in this way it is expected to plan effective programs with a minimum of coding revisions.

Again, programs will be expected to conform with CASDAC Software Specifications recently developed at DTNSRDC. These are listed below:

I. Introduction, Executable Program Specification and Glossary

II. Use and Control Specification

III. Coding Language Specification

IV. Module Organization and Design Specification

V. Programming Style Specification

VI. Program Internal Documentation Specification

VII. Requirements on Programming

VIII. Form of Deliverables Specification

IX. Processor Environments Specification

It will be appreciated that program development is planned as a more orderly process than that which has existed in the past. But the skyrocketing cost of software development demands that more formal controls be introduced into software development.

6. Computer-Aided Piping Design and Construction (CAPDAC)

It was noted in Section 5 that the mid-70's gave greater promise of development in the area of Detail Design and Construction. In the autumn of 1976, DTNSRDC was given management of a

modest program in this area. While planning studies have been initiated in the areas of hull and electrical/electronics, the greatest impact has been on the CAPDAC System, for which initial planning had been completed in 1975.

This planning comprised an Engineering Analysis of shipboard piping design, planning and fabrication. It was conducted in-house but with substantial inputs from a CAPDAC Industry Advisory Committee with members from the principal shipyards and design agents. Again, two one-week in-depth sessions were held with industry consultants covering Detail Design and Planning and Construction. These sessions resulted in a definition of the Piping Functional System consisting of 14 subsystems, 51 programs, 8 component catalogs and 14 catalogs of technical information. During these deliberations the Commerce Business Daily was used to solicit information respecting developed software. A number of replies was received and investigated. However, about the same time CAPDAC project personnel were invited to the Electric Boat (E.B.) Division of General Dynamics for a presentation on their piping design and material system software. This paralleled a number of facets of the CAPDAC system and Electric Boat was approached respecting the terms and conditions under which the software could be made available to CAPDAC. Electric Boat generously agreed to release the software for the cost of reproduction.

At a CAPDAC Advisory Committee Meeting and Workshop held in December 1976, the Engineering Analysis was approved as the vehicle for CAPDAC development. At the Workshop the E.B. software was demonstrated and participants processed a number of pipe problems deriving piping arrangement drawings and pipe fabrication sketches. With the use of scale models E. B. personnel demonstrated how piping was fabricated and assembled using their unique “Match Mark” system. Fabrication and assembly instructions are produced by computer. Implementation of their system has substantially reduced fabrication costs and has minimized the training period required by unskilled personnel entering production status.

Figure 7 gives an overview of the software. The software has many capabilities and implementation by the Navy to date provides computer-generated pipe arrangement drawings, Figure 8, and computer-generated pipe details, Figure 9. Test problems have been run for Avondale Shipyards, Puget Sound Naval Shipyard, and for Mare Island Naval Shipyard. Other shipyards are planning to submit test problems. The software is operational on the Univac Computer at the National Bureau of Standards and is currently being used by Puget Sound, which possesses the necessary Remote Job Entry hardware. It is planned to arrange for complete documentation of the software and, in addition, the acquisition of an IBM version.

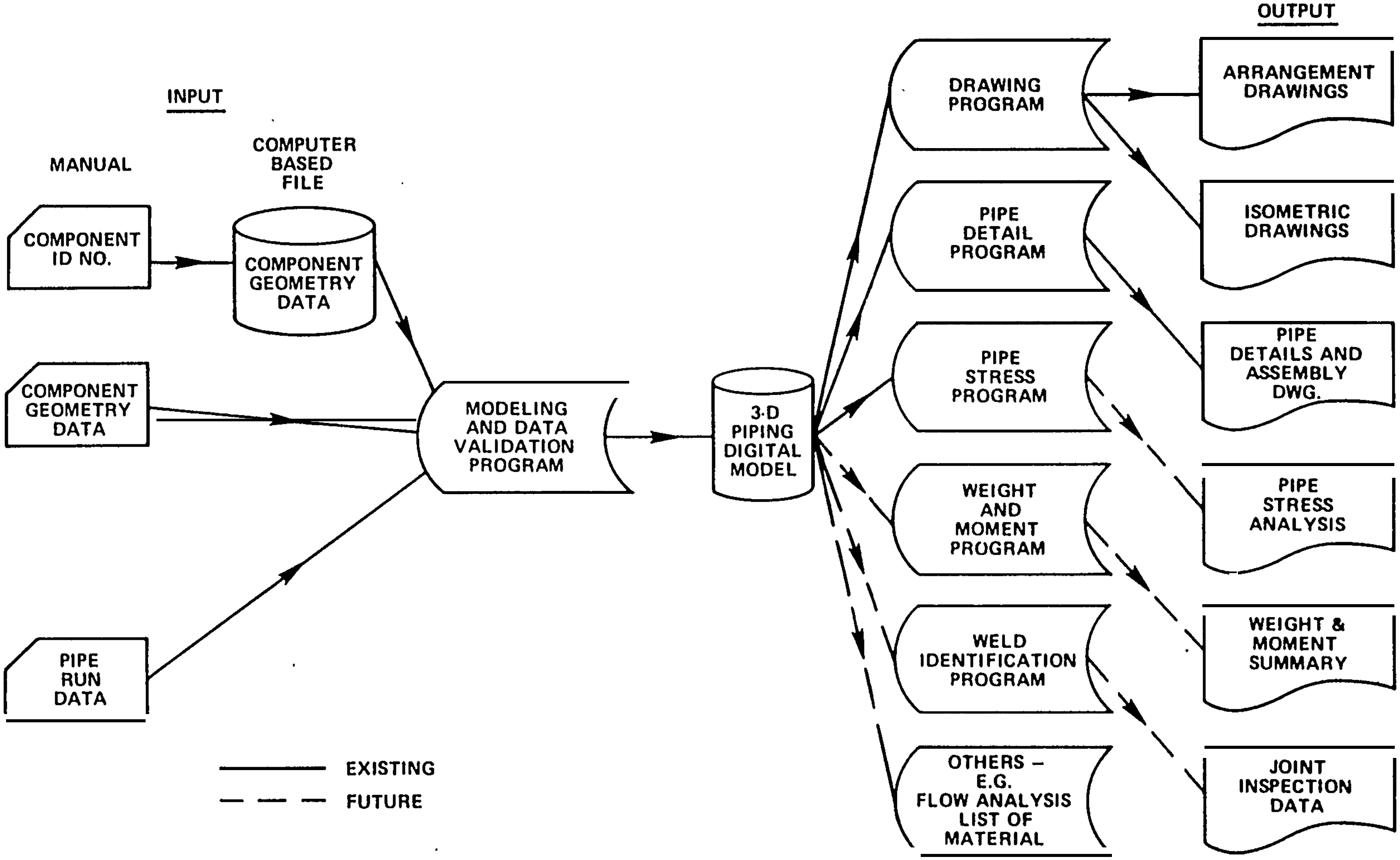


FIGURE 7 — OVERVIEW OF E. B. SOFTWARE

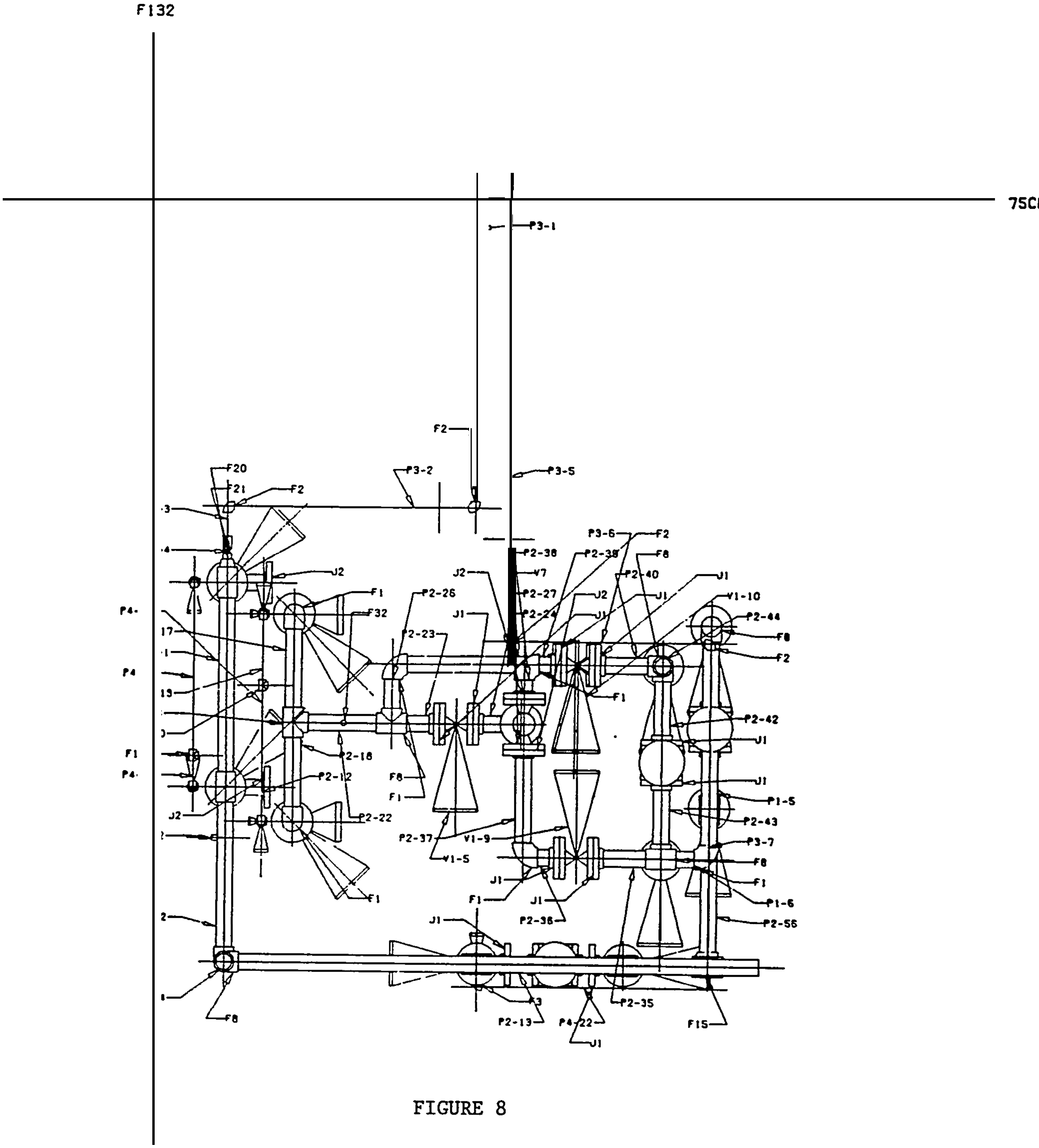

F132
75CL
P3-1
F2
P3-2
P3-5
F20
F21
F2
J2
F1
F32
P2-26
P2-23
J1
J2
V7
P2-38
P2-27
P2-24
P3-6
P2-38
F2
F8
P2-40
J2
J1
J1
V1-10
P2-44
F8
F2
F1
P2-42
J1
J1
P1-5
P2-43
P3-7
F8
F1
P1-6
P2-56
P2-18
P2-12
P2-22
F8
F1
P2-37
V1-9
V1-5
F1
J1
F1
J1
P2-36
J1
F3
P2-13
P4-22
J1
P2-35
F15
F8

FIGURE 8

ADMINISTRATIVE DATA	DWG. NO.	PIPE	HEIGHT OF
	PIPE DIM.	I.D. NO.	BEND HEAD ABOVE FLOOR

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

OFFSETS OF BEND POINTS &TYPE OF JOINT

X BBENDING INSTRUCTIONS AND X
X "MATCH MARK"DATA X
X X
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

TOP VIEW **SIDE VIEW** **END VIEW**

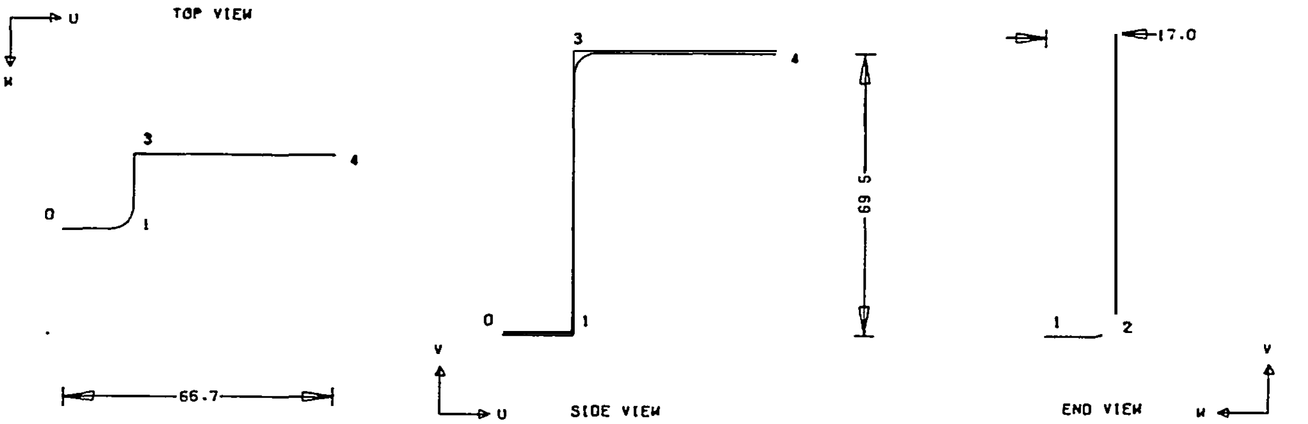
LIST OF MATERIALS
FABRICATION AND ATTACHMENT INSTRUCTIONS

* MAR 301976 NOT APPL ENGINE RM INNERBOTTOM PIPING PLAN P/O
DATE ________ BOAT NO. ___ S.O. ________
PIPEFITTER & BADGE NO. ____________
SUPERVISOR ____________

PLAN	PIPE	DET	REV APPLICABILITY	SHEET
C3-700-48-00-172	P09-2	9		12
2.375 X .218 STL		WBR	2.5 FLOOR 44	

PT NO	DELTAS U	V	W	END JOINT	BEND	ROLL ANGLE	BEND ANGLE	DIST WIRE	PBR		DIST PIPE	STRAIGHT PIPE	CLAMPING OR FITUP
•-1	18.0	.0	.0	BW	1	270	90	15.5	20	4.0	14.0	14.0	.0
1-2	.0	.0	-17.0		2	0	90	31.4	20	4.0	29.3	9.0	
2-3	.0	69.5	.0		3	90	90	99.9	20	4.0	97.1	61.5	
3-4	48.7	.0	.0	BW		270		150.0			148.1	44.7	.0

LENGTH END TO END = 97.9 INCHES



LIST OF MATERIALS

PC. MK.	QTY	SIZE	TYPE	MATERIAL	SPECIFICATION	REMARKS	LEVEL CLASS
P09	12-S	2.375X.218	PIPE	STL			

FABRICATION
P09-2 (AT POINT 4) ATTACHED TO P09-1 OF DETAIL 8

FIGURE 9 – COMPUTER GENERATED PIPE DETAILS

The development of the CAPDAC system will be by both in-house **effort at DTNSRDC and by contract with industry. The current in-house effort involves the development of a skeletal , CAPDAC. Subsystem for Composite Drawings. Figure 10 depicts the systerm in simple-terms. ,Development is such as to permit the preparation of the input data from a centerline run of piping either by a digitizer (Alt 1) or by card input (Alt 2). The " system will create a 3-dimensional digital model of the piping system. There will also be a generalized 2-dimensional drafting capability to permit the preparation of systems other than piping. The skeletal system will have a limited data base of piping and machinery components and will not include the interface of engineering application programs. The complete development of this system will be by contract with the Industry. Other areas of CAPDAC are currently under development and the processing of a number of contracts has been initiated.**

7. Related Endeavors

Naval architects, engineers and managers are generally concerned with' application programs which process their work. The success-of these programs depends not only on the.engineering algorithms used but equally on the computer science base, 'i.e., the computer operating system, library routines high-level language compilers, data storage media, data manipulation techniques, etc. As application programs become more sophisticated the computer science base demands increased sophistica- ,tion and extension.

Considerable attention is now being directed toward the computer science side of computer-aided design. The Office " of Naval Research (ONR) is initiating work in this area and the Navy is also following with interest two other large developments, one by the National Aeronautics and Space Administration and the other by the Air Force.

(a) Office"of Naval Research - Computer Science Project

ONR is initiating a program directed toward identifying the computer science techniques required to enhance and extend computer usage in shipbuilding. The first meeting is to be held on 29 June in Washington and attendees have been invited from shipbuilders and design agents, universities and other institutions, and Navy and other government agencies. Computer-aided ship design and construction requirements in computer science will be discussed under the general topical areas:

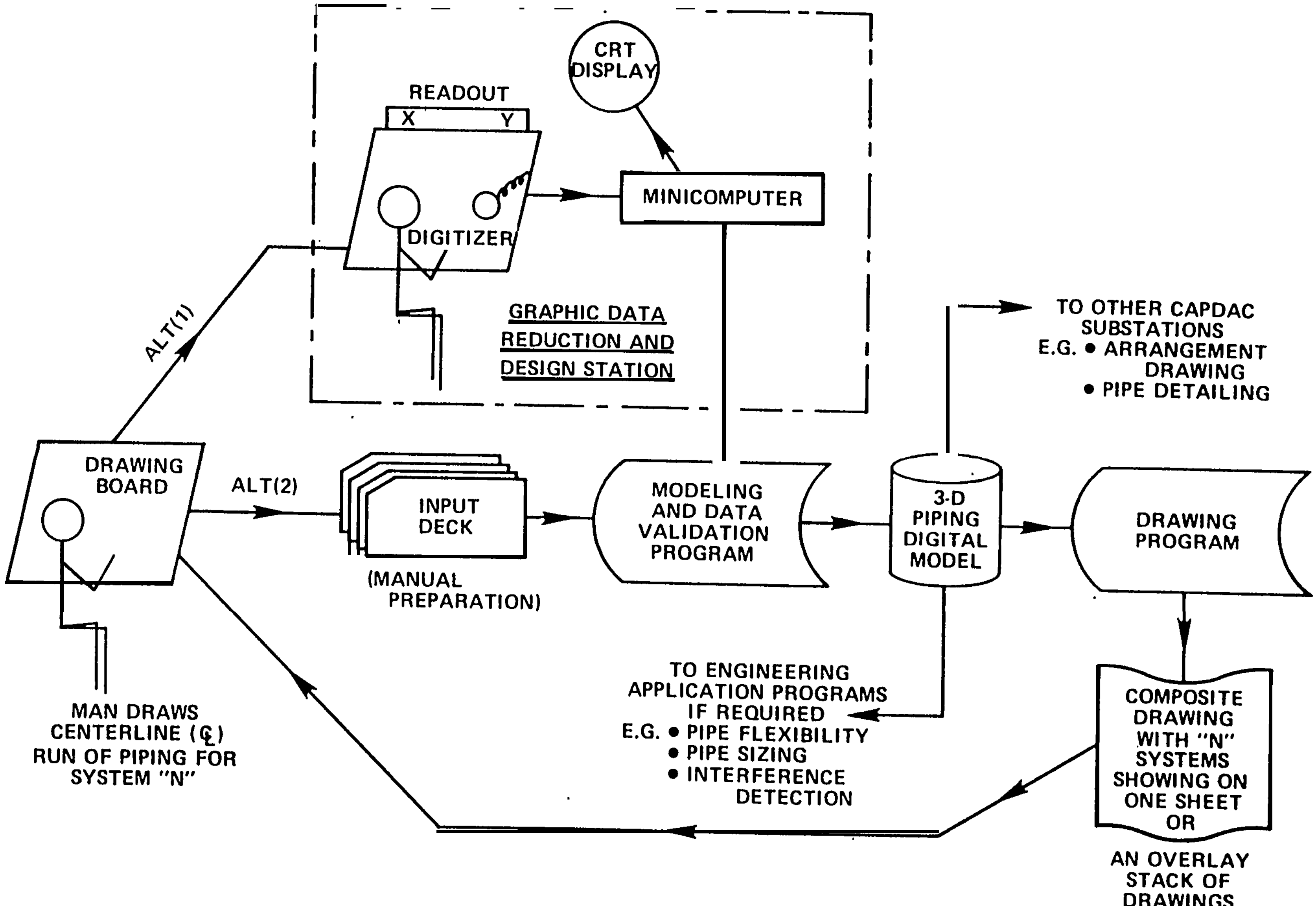


FIGURE 10 — CAPDAC COMPOSITE SUBSYSTEM

- Computer systems requirements analysis

- Computer systems (hardware and software) design and implementation

- Information management

- Interactive systems and graphics

- Networking and distributed computing

- Automation technology

It is expected this meeting will review the.problem areas, identify and attempt to prioritize needs, suggest potential solutions and develop a program to address the needs identified.

(b) National Aeronautics and Space Administration - Integrated Programs for Aerospace-Vehicle Design (IPAD)

This is approximately a five-year $10 million effort for the National Aeronautics and Space Administration (NASA). The principal contractor is Boeing. IPAD has been briefly defined as software to computerize, inso far as possible, company-wide design information processing. Its intended scope is such that it will simultaneously support design activities of a typical company mix of multiple development projects. It will serve management and *very* large engineering staffs at all levels of design (conceptual, preliminary, and final) and will aid in the assembly and organization of design data for support of manufacturing processes.

IPAD software will function on "third generation" computer complexes typical of those in use today by large aerospace corporations and will augment, rather than replace, existing "system software." It is currently visualized as composed of (1) executive software that will control user-directed processes through "interactive" interfaces with a large number of terminals in simultaneous use by engineering and management personnel; (2) a large number of utility software packages for routine information manipulation and display functions; and (3) data management software to provide a comprehensive, versatile capability for efficiently storing, tracking, protecting, and retrieving exceptionally large quantities of data maintained on multiple storage devices.

The data base includes the technical analysis and design computer programs utilized by various disciplinary specialists. Such programs are not regarded as part of IPAD, but must be provided by the user to form the complete design-software system; they can include existing and future company-proprietary programs, as well as those in the public domain. The data base will also include all official project information defining the characteristics of current baseline and alternative designs and their performance, as well as archival "handbook" information forming the technology base for company designs. Simultaneous access to the same baseline design information by all disciplinary groups Will thus be possible. Temporary libraries, for design information being actively utilized by individuals or teams, will also be provided.

A substantial effort was mounted in 1975 to determine the feasibility of IPAD and some 83 industry representatives attended the final feasibility briefings. IPAD has now been under development for approximately a year and project guidance stems from an Industry Technical Advisory Board consisting of 18 aircraft industry members representing 14 aircraft companies together with three computer industry representatives.

(c) Air Force - Integrated Computer Aided Manufacturing (ICAM)

This is a five-year $75 million effort by the Air Force under the Manufacturing Technology program to develop a system that will replace the existing patchwork of computers with one that is integrated from the outset. To date three tasks have been awarded:

Task I - to Softech - to develop an architectural model that blueprints such manufacturing complexities as machines, materials, processes, designs, information, -procedures, people, and organizations.

Task II - to Softech - concerns group technology in which parts and processes are grouped according to common features.

Task III - to Boeing - the assessment of sheet metal formability and assembly technology.

Other tasks will be awarded as the project progresses. In addition, considerable work has been done by the National Bureau of Standards to analyze those existing standards which are

relevant to the ICAM Program and to outline a policy to achieve Air Force programmatic objectives through the use of standards.

Again, some eight major aircraft companies are involved in the project as well as consultants from various universities and institutions. A joint Air Force - NASA agreement pledges cooperation in areas of mutual interest.

8. Concluding Remarks

The paper presents some aspects of Computer-Aided Ship Design and Construction in the Navy and attempts to set down some current philosophies. These are that software production is becoming more formal, that computer science limitations increasingly constrain the degree of sophistication that application programs can include, and finally, a reiteration of the absolute necessity of user participation in program planning and development.

Probably the most difficult technical problem at present is the approach and determination of a data structure and a data base management system which could permit data to be shared readily among all the various disciplines involved in shipbuilding. If we further suggest this software be portable to different computers, including minicomputers, the difficulties appear insurmountable at this time. It is of interest to note the IPAD approach to this problem, which is probably to adapt an existing data management system. Portability is planned to . be achieved by successive conversion and implementation on a range of computers. The proposed ICAM solution is to develop comprehensive data mangement requirements and specifications and solicit proposals from the software industry.

The current Navy philosophy is to develop stand-alone programs and possibly stand-alone subsystems on the computer most used by industry and to recognize that an integrated detail design and construction system is a longer-term goal. As a practical matter, of course, this will mean that the near-term emphasis will not be on computer science but rather on application programs with good potential for dollar and time savings. And the development, implementation and acceptance by industry of such programs is essential if Navy support for the CASDAC project is to be maintained and augmented.

Respecting user involvement, the brief discussion of IPAD and ICAM in Section 7 emphasized the substantial aircraft industry support in those developments. Navy work in CAPDAC has been handsomely supported by our shipbuilding industry, and"Navy developments in hull, machinery, electrical, etc. would be greatly encouraged if closer ties with industry in those areas can be forged. Such support is desirable not only at the technical level but also at the executive level.

In conclusion, I would like to extend my hearty thanks to REAPS for the use of this forum to present some current philosophies of CASDAC.

RECENT DEVELOPMENTS IN COMPUTER BASED SYSTEMS AT KOCKUMS

Kai Holmgren
Kockums Computer Systems AB
Malmo, Sweden

As the Director of Kockums Computer Systems, Mr. Holmgren is responsible for all its activity (development of systems, marketing, computer production, etc.). He has been with Kockums in various positions since 1961. Before that time, he was in charge of technical systems development at the Swedish Aeroengine Company.

KOCKUMS

THE KOCKUMS GROUP

KOCKUMS AB

Group Staff
- Finance
- Personnel
- Legal
- etc

Employees 1977

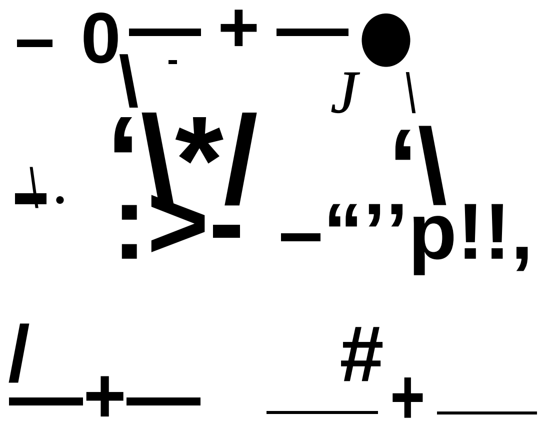
.8.000

Turnover 1976

.430 million dollars

Division	Activities
Shipyard	Ships Submarines
Shipping	Shipping operations
Computer Systems	Computer based systems Computer operations System services
Industries	qf highwaj@qcAk4;. *rnp trucks tiggin twhicles "and systemd~, Sqwmil] fe equipment and systefi
Automation	Marine electronics Acoustic signalling equipment Sawmill electronics Electronic lifting devices
Chemical	Biochemical indicators
Construction	Feed-stuff plants Installations for powdered materials
Energy Systems	Heat and power production plants District heating systems System components

Information System

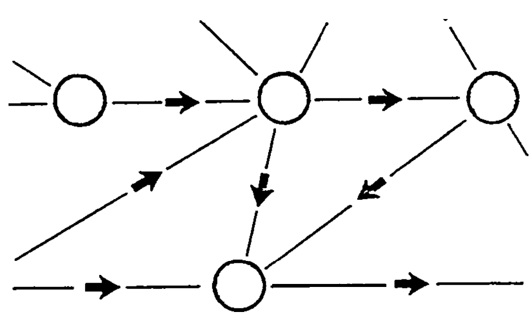


- <u>Stations</u> (Departments, persons, machines etc)

  producing
consuming
handling information

- <u>Transportation ways</u>
- <u>Information media</u> (documents, files, data bases etc)

Computer- based *Information System*

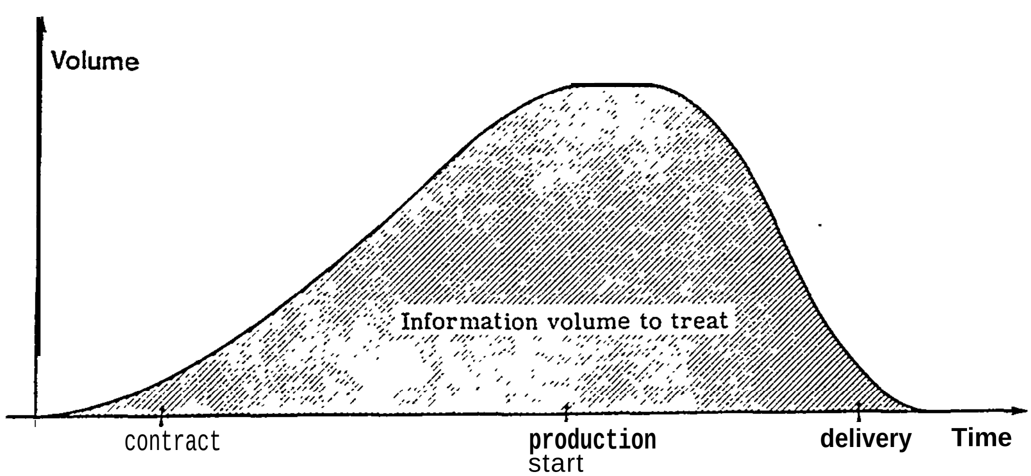


- Network covering the main activities of a company
- A major part of the activities are covered by computer applications
- The individual computer applications are designed so that they can "talk" to each other

Characteristics of Shipbuilding

- Tailor-made product
- Short series
- All activities concentrated around one complicated and expensive product
- Different types of design activities (Hull, out-fitting machinery)
- Different types of production
- Heavy product requiring extensive areas, transportations and lifting
- Much work done out-doors
- Steel is costwise almost 50 % of the total material

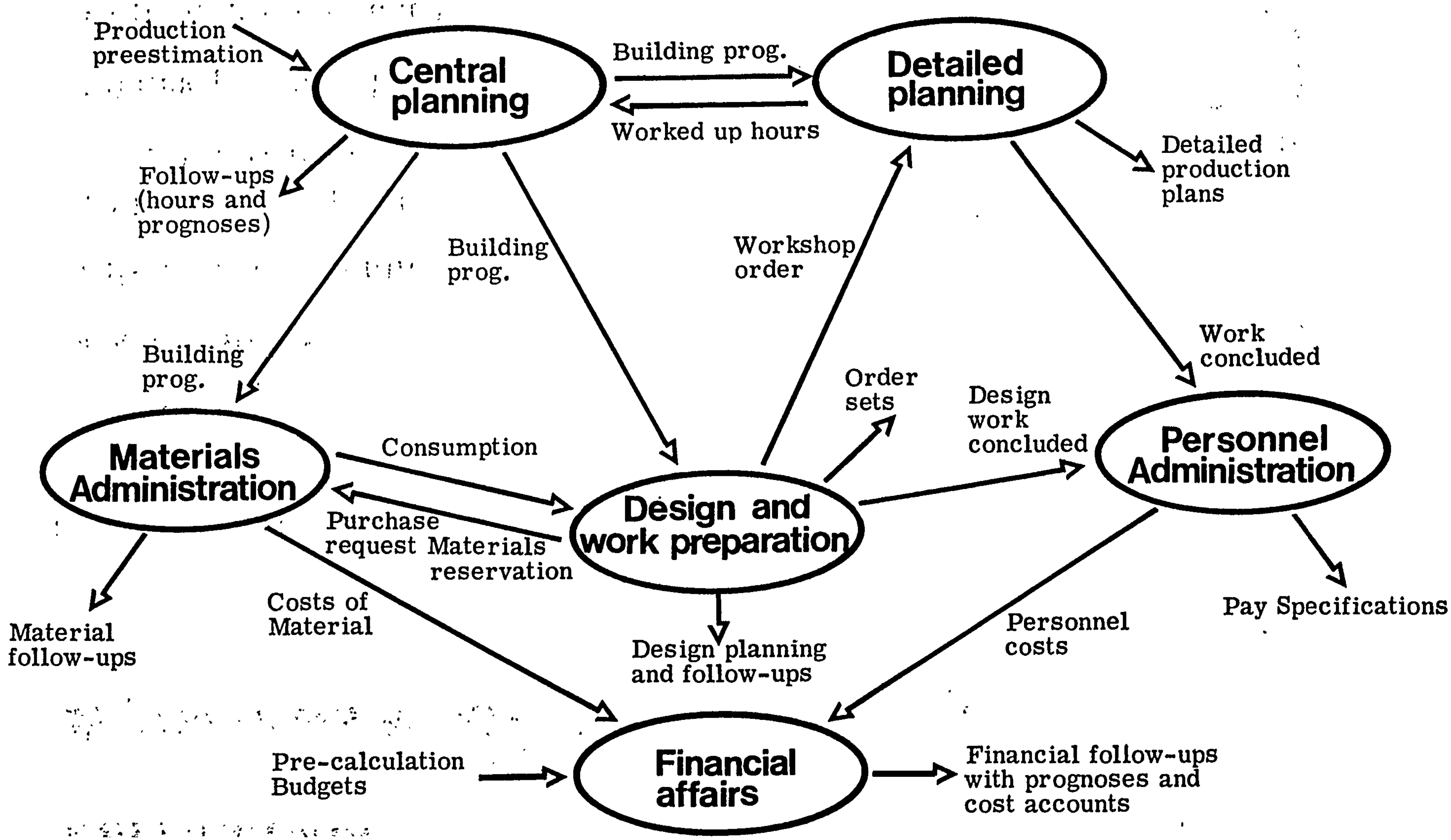
Information Structure



- Large volumes of design and work preparation information (short series)
- Material information and standardization very vital.
- The overall planning and follow-up is very essential (a ship represents a big and complicated project)

KOCKUMS

Survey SYSTEM



KOCKUMS

Display screen terminal

Inquiry / Dialogue

- Material status
- Work status
- Resource planning
- Plate and profile administration
- Work preparation
- Financial accounting
- . . . .

KOCKUMS

The planning function

Central planning 

Detailed planning – design

Drawing offices			
Hull P	***Electrical*** F	***Outfitting*** W	***Machinery*** *F*

Detailed planning – Production

Workshops		
Hull 4!+% components	***Hull w 10utfitting ~ assembly***	***Machinery~***

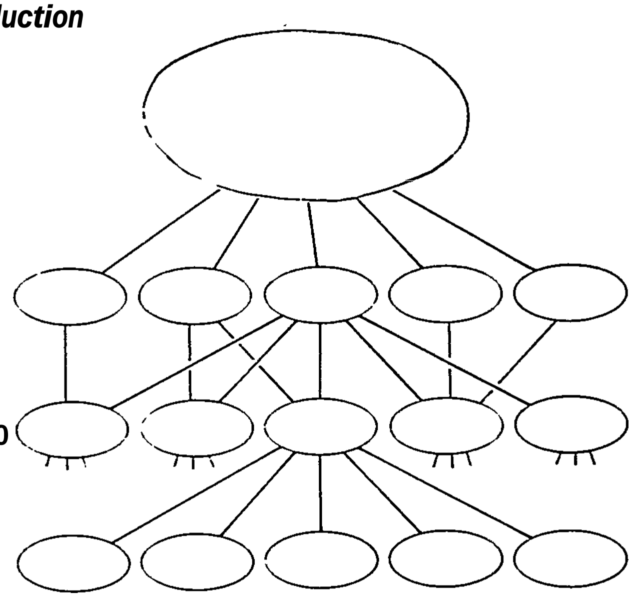
KOCKUMS

Planning levels for production

Planning units 1,000

Workshop orders 8,000

Jobs 80,000

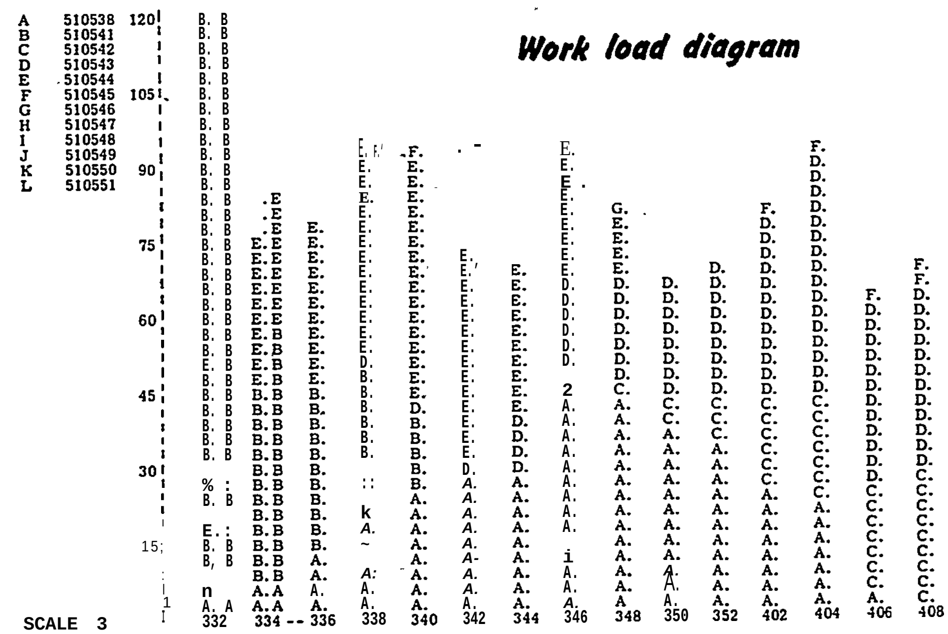


KOCKUMS

KOCKUMS MEKANISKA VERKSTADS AB
OH303A
WORK CENTRE: 729 -736

WORK LOAD DIAGRAM 1 PAGE 2-1
730827 WORKLOAD SCHEME

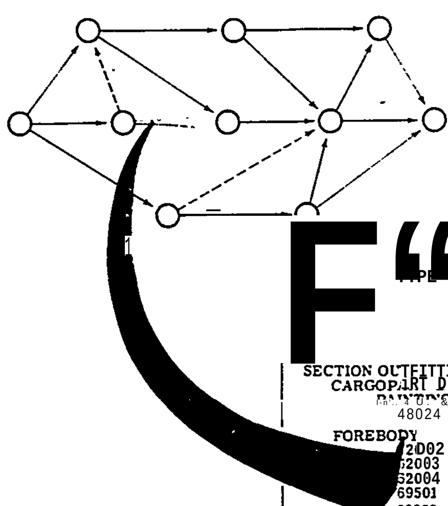
Work load diagram



SCALE 3

X KOCKUMS

Conversion of a network into a building programme



F“” ‘RODucT

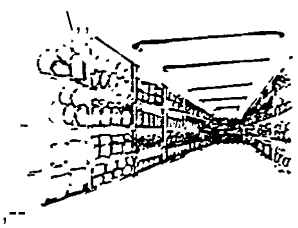
TYPE NO ZCSEELAY FLOAT OIJTDOCK DE$WXVEXRY

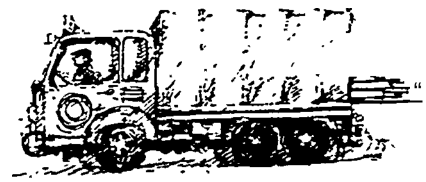
s o 510-549
PAGE: 25

	DELIVERY WEEK DRAW-INGS	MA-TERIALS
SECTION OUTFITTIMi		
CARGOPART D SECTIOX		
48024 D796BB READY-hL4DE FOR SEC OLTF	---	515
FOREBODY		
72D02 FOREBODY OLTF. IN HULL DEPT	446	504
62003 El 391 SEC OUT	501	509
62004 B 991 READY-h2ADE FOR SEC OUTF	---	513
69501 PIPETOWER	446	504
69502 PIPETOWER READY-MADE	---	506
Deckhouses		
71302 H702 SEC OUTF	503	511
71304 H702 READY-MADE FOR SEC OuTFF	---	513
71503 H703SB SEC OUTF	502	510
71504 H'i03SB READY-MADE FOR SEC OUTF	---	510

KOCKUMS

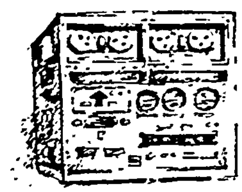
50,000 kinds of materials





10,000 (stock materials)

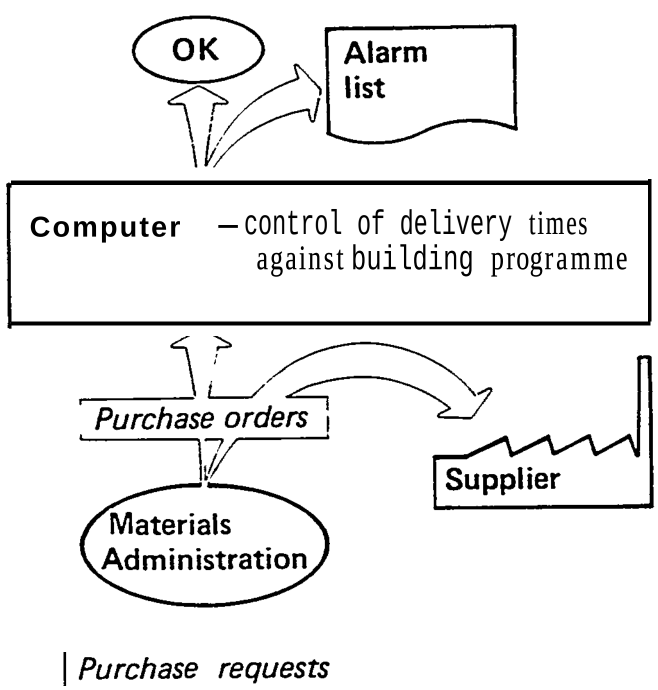
Ordered by the computer



40,000 (direct materials)

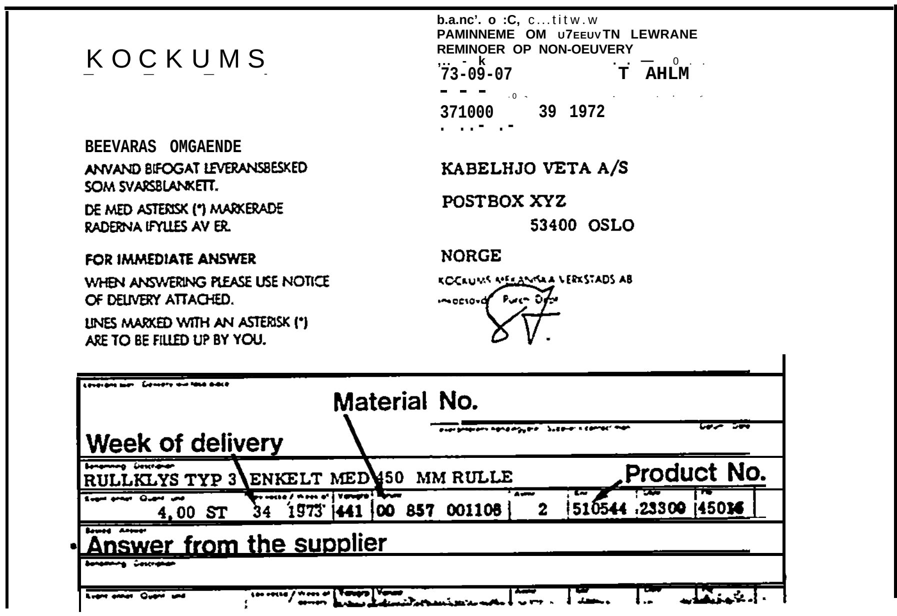
Ordered by the designer

KOCKUMS



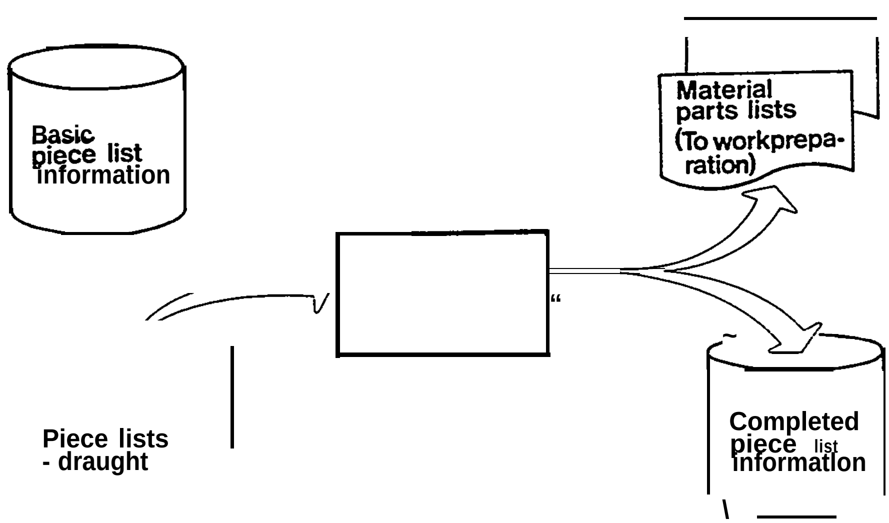
KOCKUMS

Reminder of non-delivery



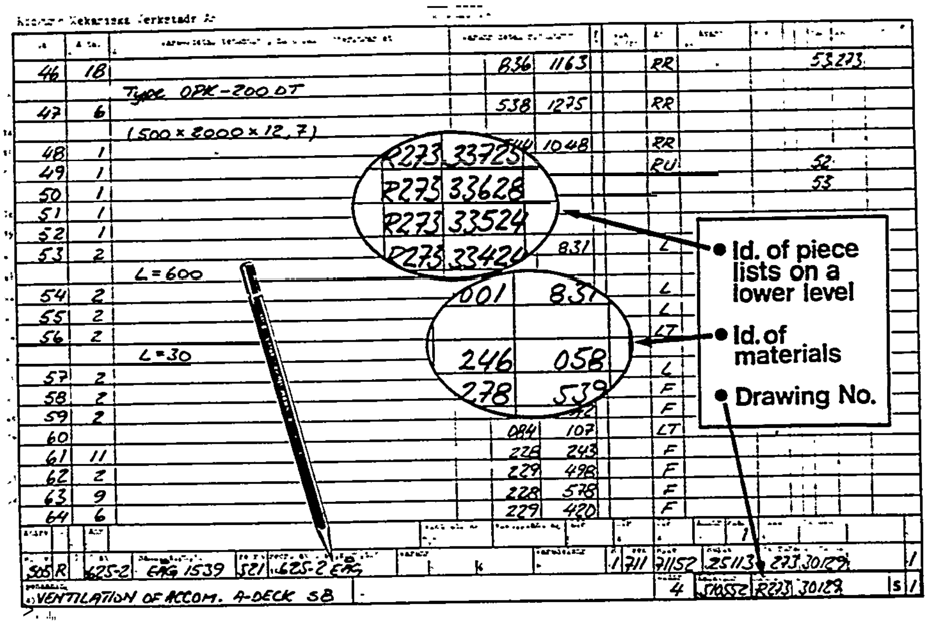
KOCKUMS

Data bank for piece list information



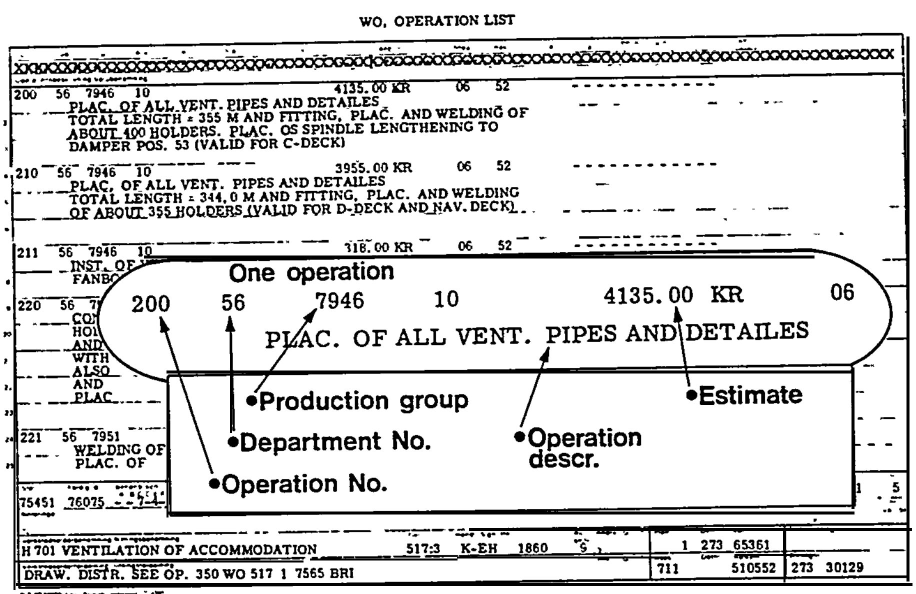
KOCKUMS

Piece list — draught



KOCKUMS

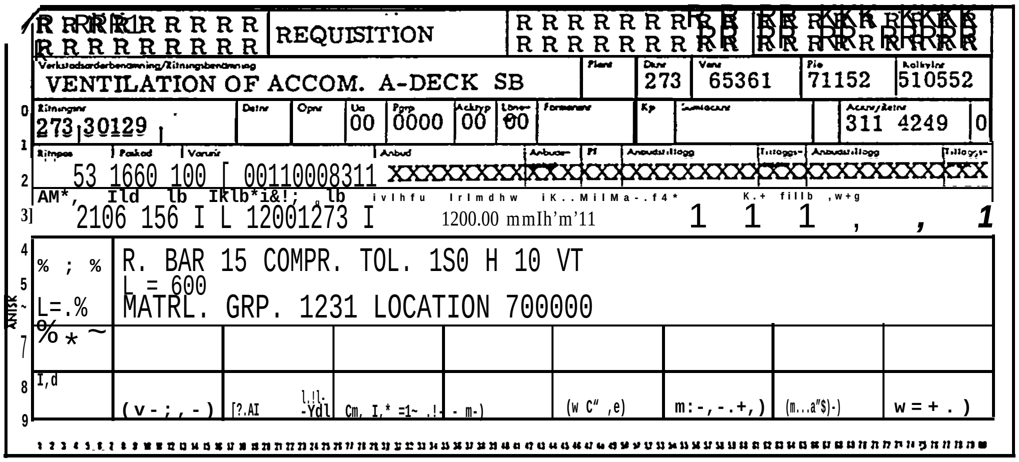
Operation list



KOCKUMS

Order-set–material requisition

- •Product No.
- •Planning unit
- •Reference No. with check digit
- •Material No.
- ● Planned quantity
- ● Required quantity (filled in manually)


REQUISITION

VENTILATION OF ACCOM. A-DECK SB | 273 | 65361 | 71152 | 510552

273 30129 | 00 | 0000 | 00 | 00 | 311 4249 | 0

53 1660 100 [00110008311 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

2106 156 I L 12001273 I 1200.00 1 1 1

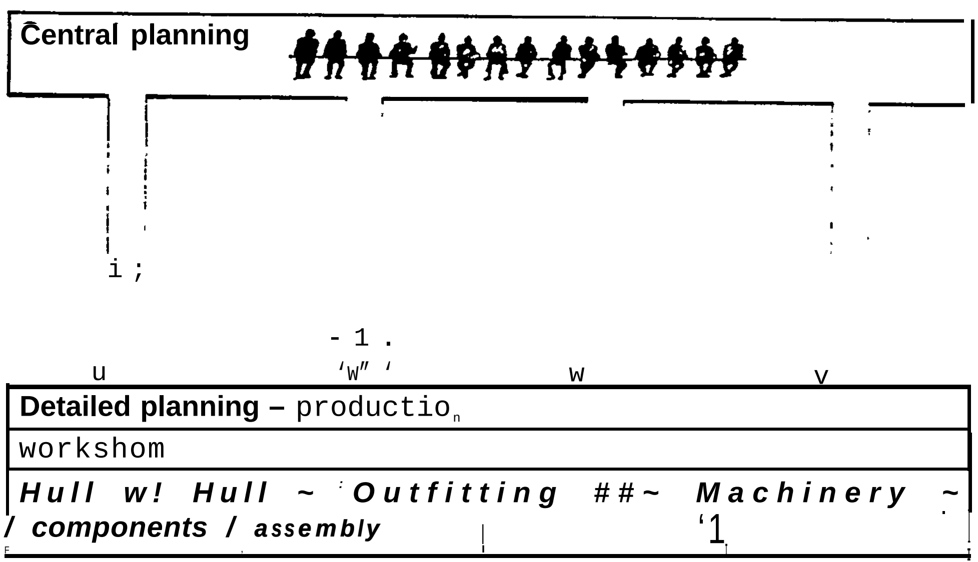
R. BAR 15 COMPR. TOL. 1S0 H 10 VT

L = 600

MATRL. GRP. 1231 LOCATION 700000

KOCKUMS

The planning function



KOCKUMS

Detailed plan for Workshops

KOCKUMS MEKANISKA VERKSTADS AB
OUTFITTING
QD1128

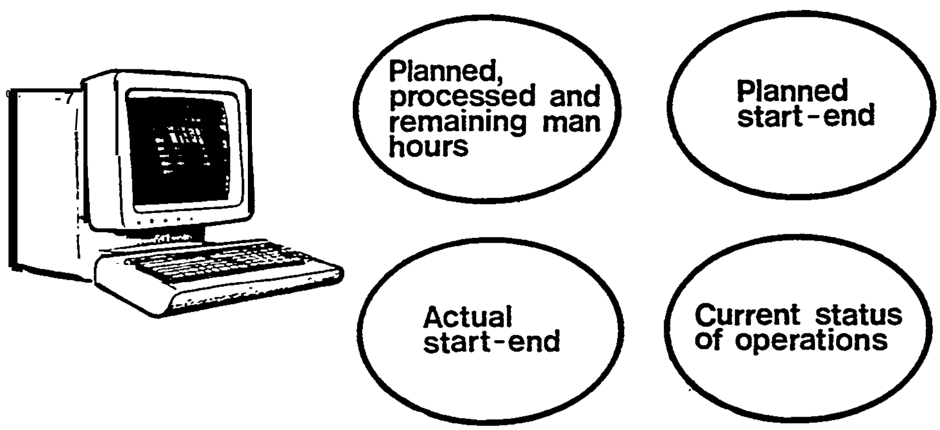
PRODUCTION PROGRAMME
① DEPT 734 ORDERDISTRIBUTION AREA 911
73-03-23

PRODUCT NUMBER	WORK SHOP ORDER	PLAN UNIT	JOB ②	PROD GROUP	PLAN HOUR ③	CAPACITY	START	FINISHED ④	STATUS	WORK ORDE DESIGNATIO
510539	59674	45015	10- 20	7046	16.7	0.8	73061	73085	8P	[illegible]
510540	56848	32603	10- 20	7946	11.2	0.8	73081	73084	P	G 402 PLAC
510540	57093	32603	10- 20	7946	10.9	0.8	73 08]	73084	P	[illegible]
510540	44327	24513	40	7946	3.0	1.0	73082	73095		
510539	57179	71398	50- 70	7046	16.1	0.2	73082	73105	P	H-702 OUt
								ACCUMULATED		1408
REMAINING HOURS WEEK 7308 289										
510539	55410	62703	140- 150	7946	16.0	1.1	73091	73094	-----	8903 [illegible]
510539	56960	38603	30- 70	7046	[illegible]	[illegible]				

- Identification of department and order distribution area ①
- Identification of a job ②
- Planned man-hours ③
- Starting and completion time ④

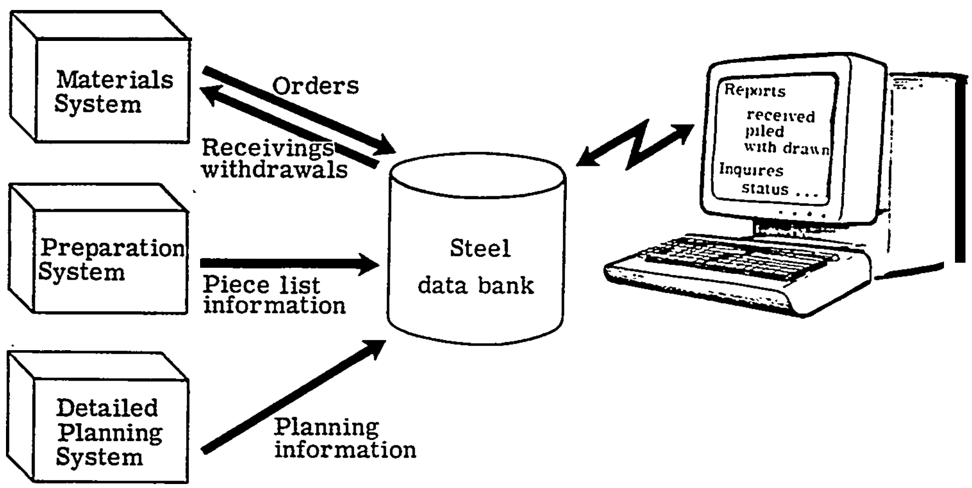
KOCKUMs

Production situation for a work order ?



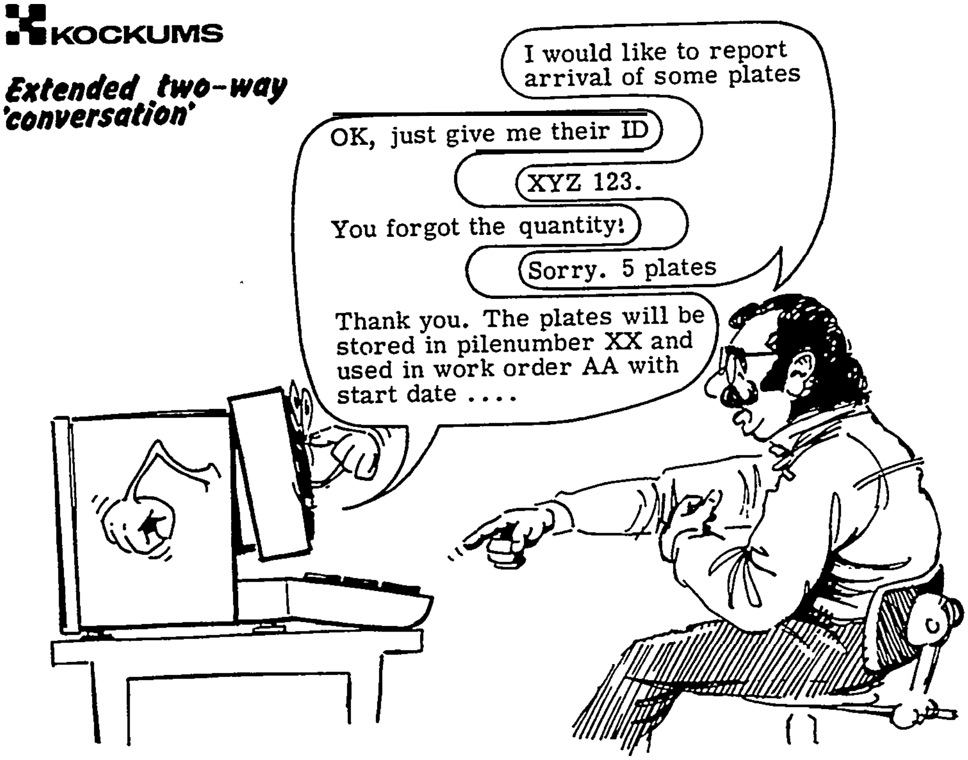
KOCKUMS

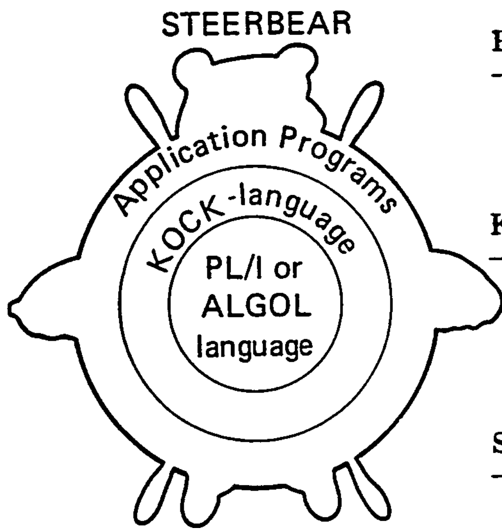
Steel administration system



KOCKUMS

Extended two-way 'conversation'





PL/I or ALGOL
— a general programming language

KOCK
— a programming language with geometry and data bank facilities

STEERBEAR
— an integrated system for shipbuilding application

C 302

Main features
of KOCK language

1 All PL/I or ALGOL available

2 Data base formats for

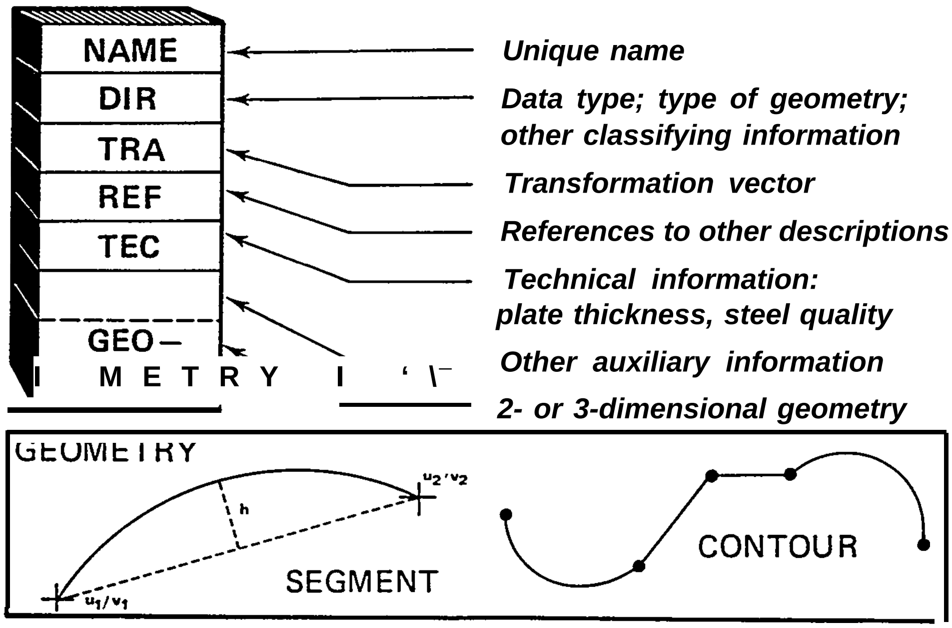
- Geometry
- Tables
- Arbitrary information

3 Extensive subroutine system for

- Data base operations
- Geometry and table handling

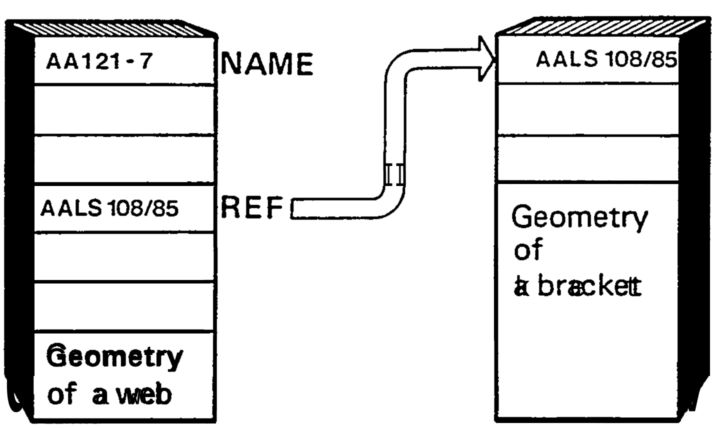
C 303

KOCK description in the data bank



c 305

Reference between KOCK *descriptions in the data bank*

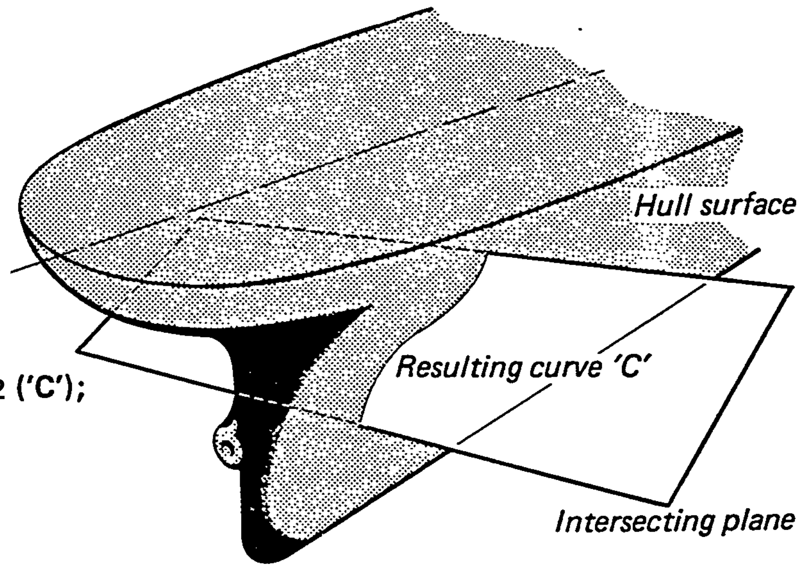


Cut surface with plane

CALL T32 ('C');

Result

Curve 'C'
generated
and stored

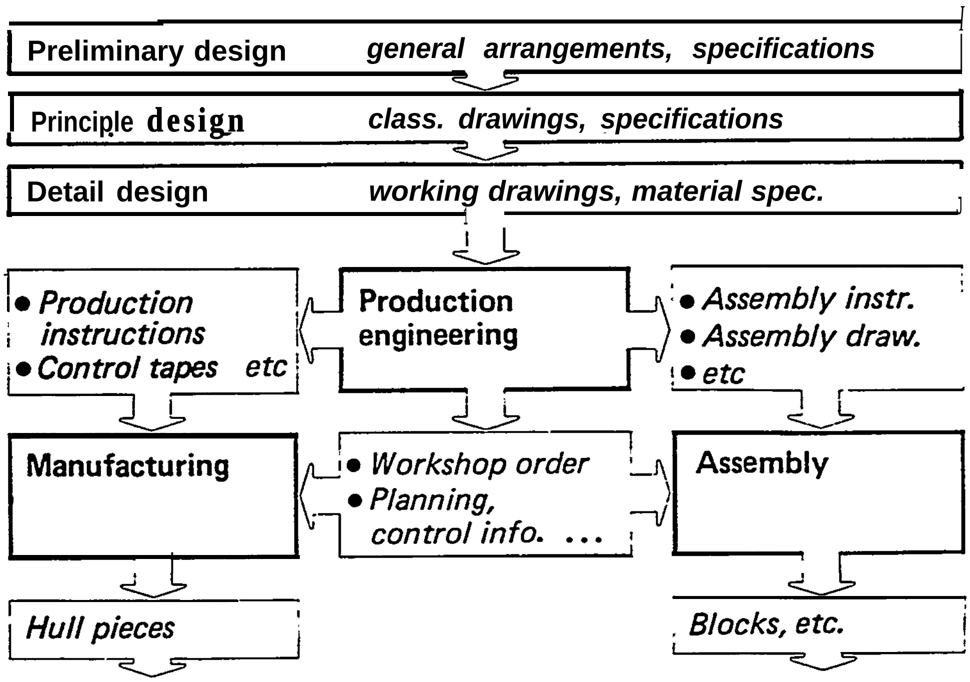


c 501

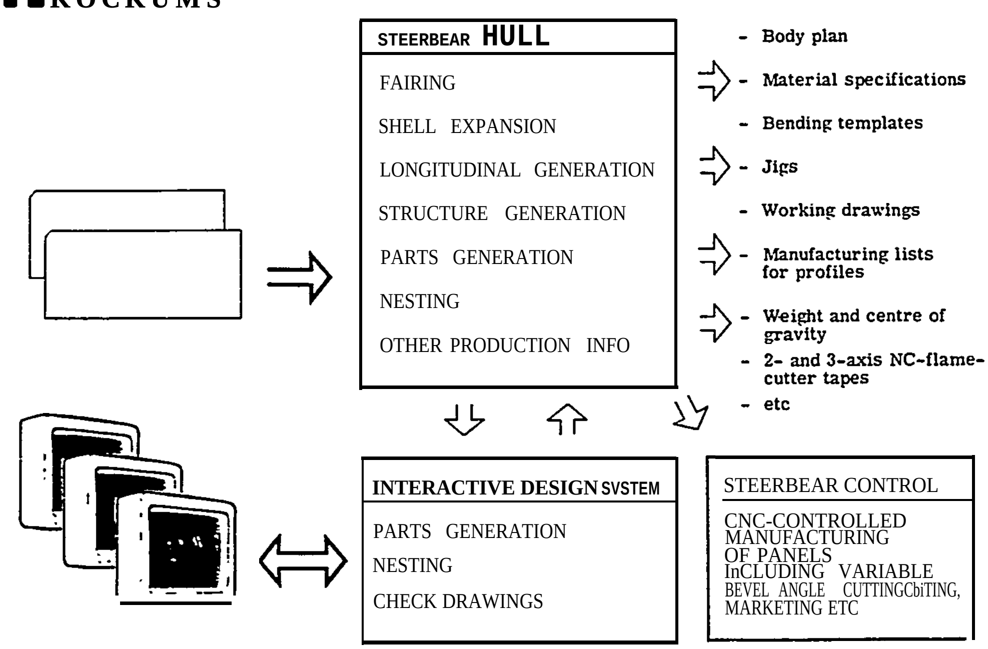
Some typical application subroutines

Hydromechanical calculations	• T61 — Moment of surface • T64 — Simpson integral • ...
Nesting	• PA3 — A nest • PM18 — Along to corner • PD1 — Draw text • ...
Generation of hull pieces (micro design standards)	• T200 — Generate outer contour • T232 — Set cutouts • T300 — Tripping bracket • ...

Principle flow – design and production

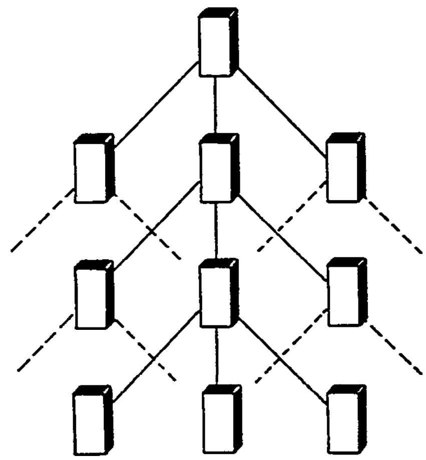


KOCKUMS



C 304

Hierarchy in data bank

		Example
Hull reference		**AA HULL 546**
Building blocks		**AA 121**
Panels		**AA 121–7**
Hull pieces		**AA 121–7–S250P**

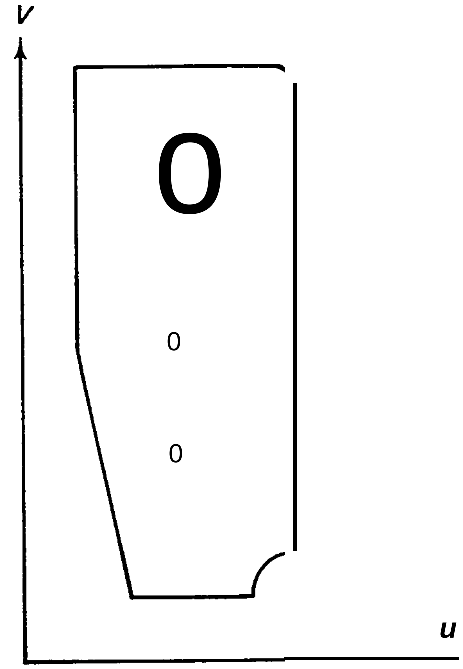
C 506

Hull structure generation

Generation of panels	. Brackets • Scallops, cutouts, holes • Stiffeners, flanges • ...
... ***can be done by***	• KOCK programming <u>or</u> • Structure programming
... ***based on***	• Micro design standards • Special set of application subroutines • Structure data bank

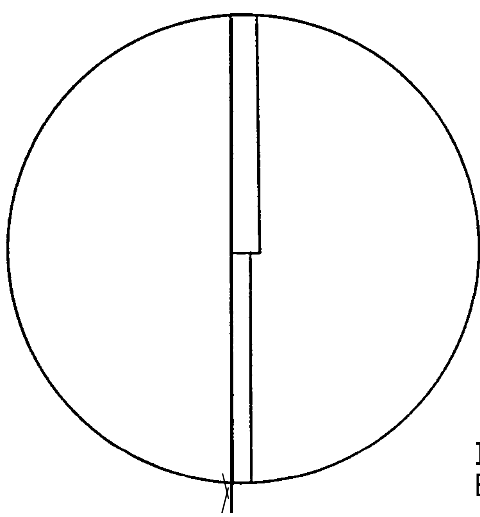
Simple KOCK program

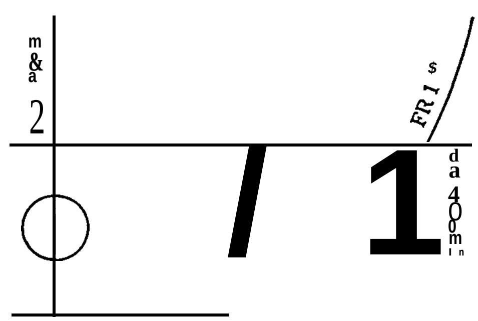
```
...
INITIATE KOCK (2000);
TREAT (≮TESTEIT≯);
POINT (200,100);
SEGMENT (0,425,100);
CIRCLE (-75,90,90);
SEGMENT (0,500,1050);
CIRCLE (50,90,90);
LINE WITH ANGLE (180,350);
LINE WITH ANGLE (270,500);
SEGMENT (0,200,100);
FOR V = 450,650,900 DO
IF V<900 THEN
ADD CIRCULAR CONTOUR (300,V,50)
ELSE
ADD CIRCULAR CONTOUR (300,V,75);
NREA = 1;
REA (1) = 14.5;
PUT RECORD (≮DIM≯,2,-1);
KOCK DUMP (≮TESTEIT≯);
DRAW DESCRIPTION (≮TESTE
TERMINATE KOCK;
...
```



KOCKUMS

Panel boundaries





INPUT:
BOUNDARY, FR148/V=5200/'AG162-3'

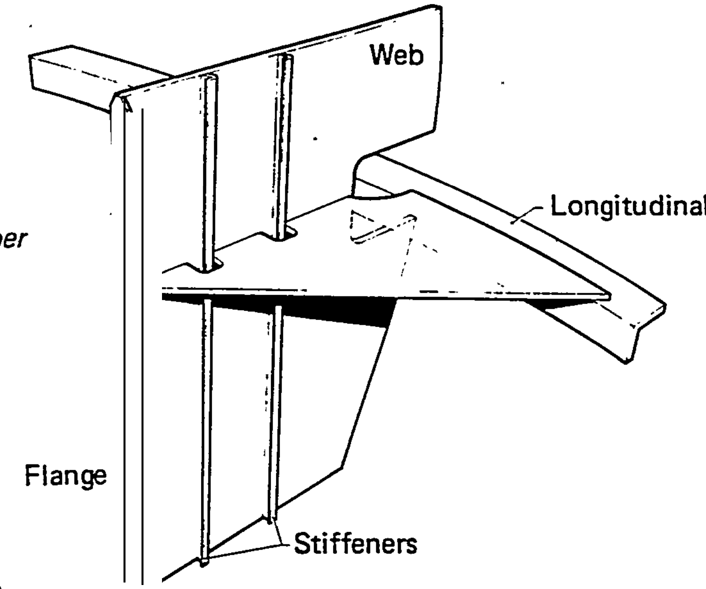
Tripping bracket

Input:

- *Connection code*
- *Longitudinal number*
- *Thickness*
- *Side*
- *Quality*

Result:

The bracket generated and stored



KOCKUMS

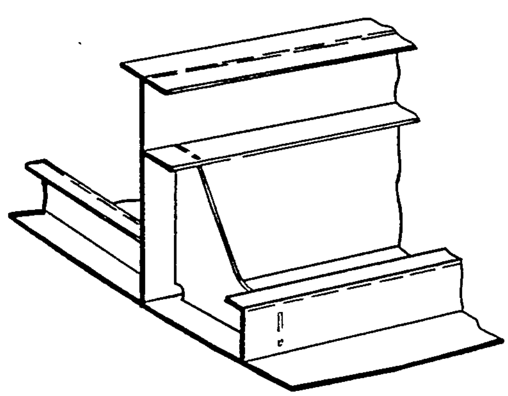
Special bracket

INPUT:

- References to longitudinal curve, surrounding panels, profiles etc.
- Some measurements
- Thickness
- Quality

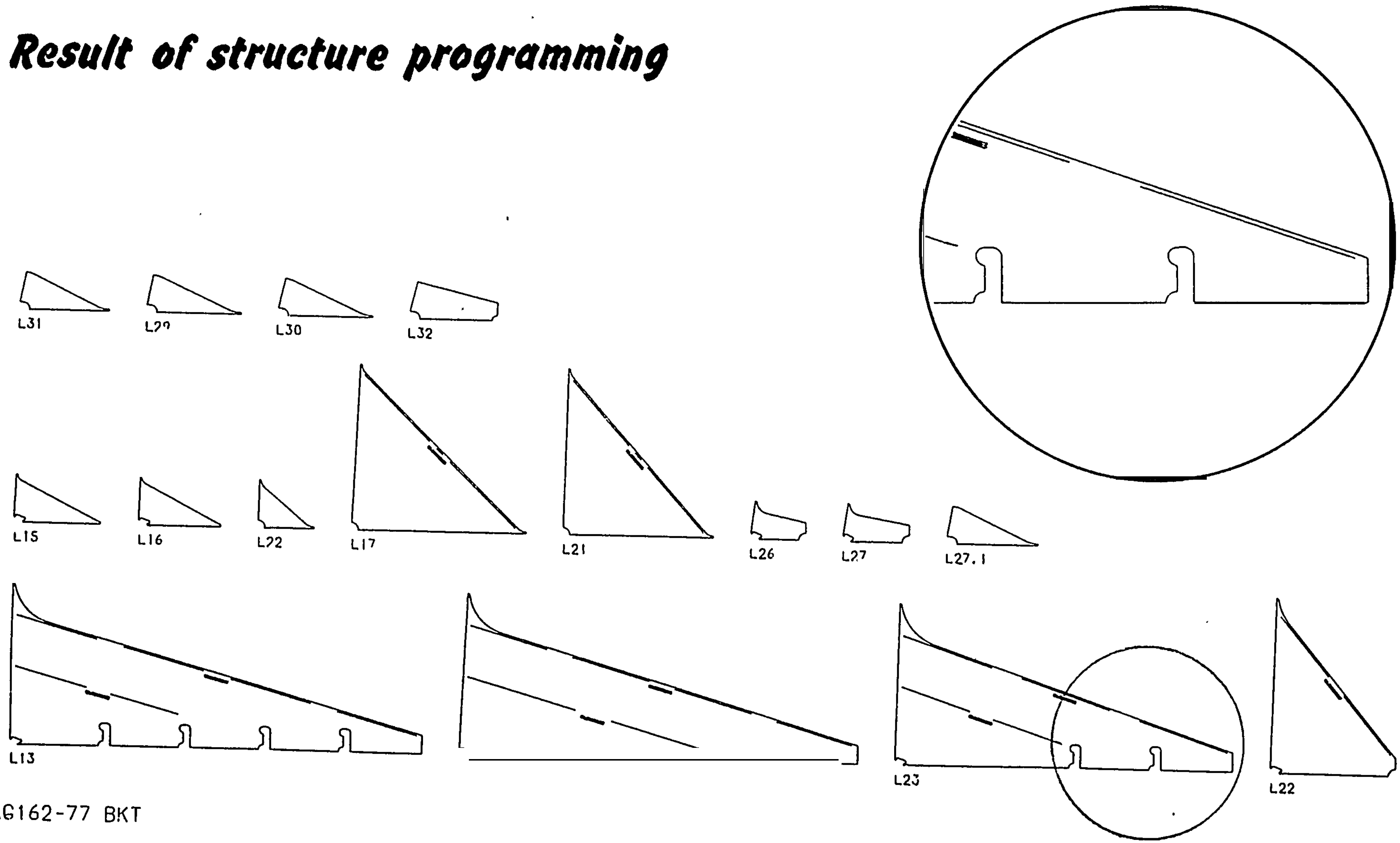
RESULT:

The bracket generated and stored.



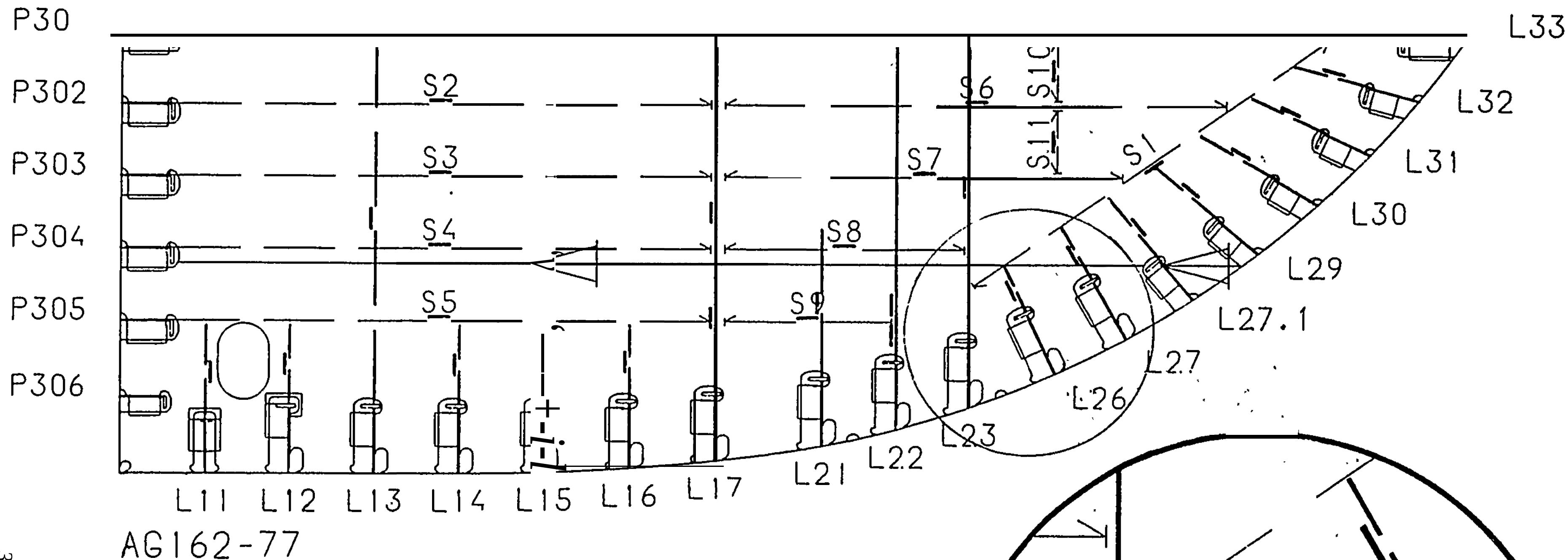
KOCKUMS

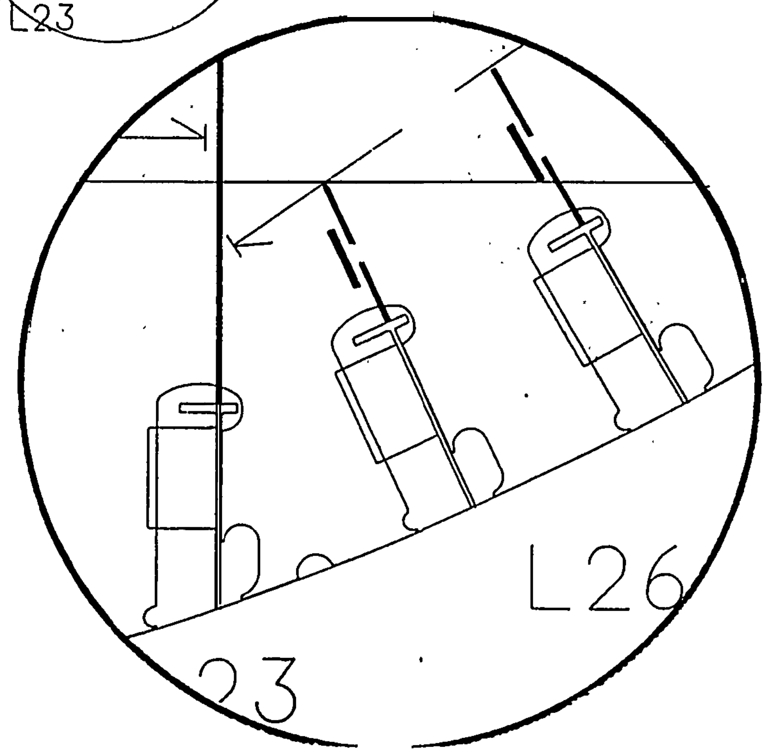
Result of structure programming



AG162-77 BKT

KOCKUMS

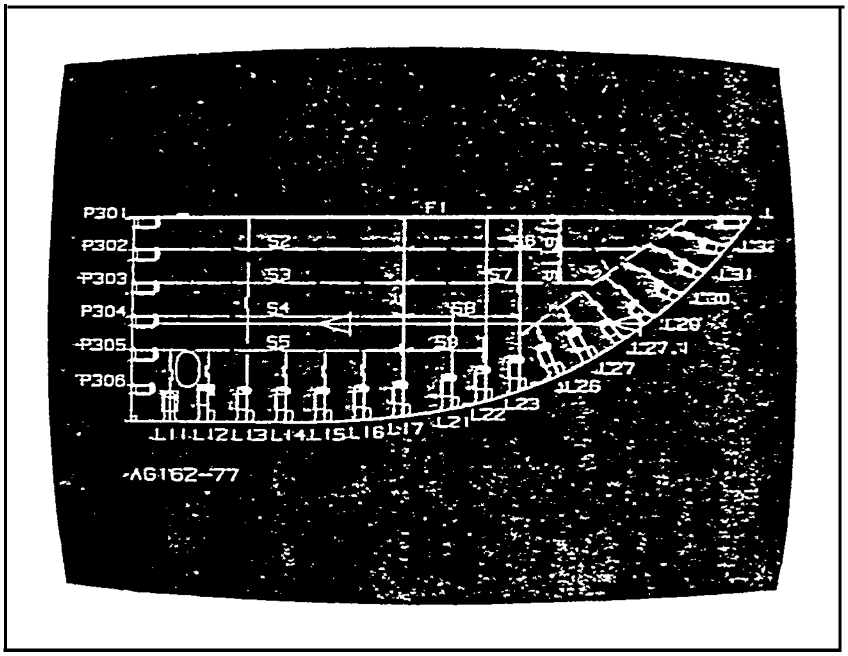




Result of structure programming

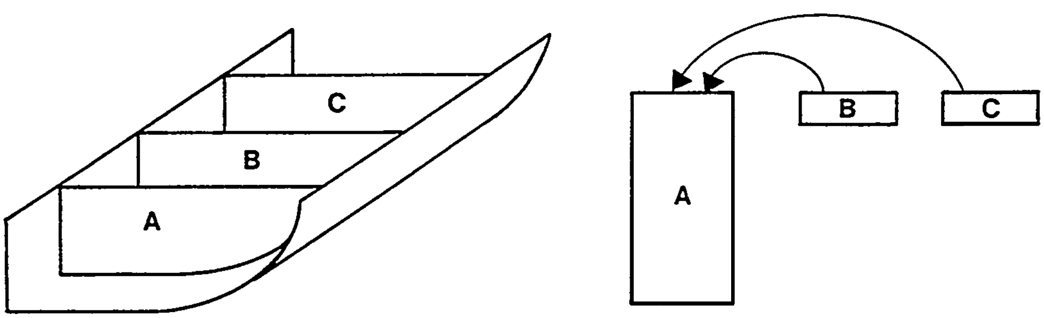
KOCKUMS

Check drawing



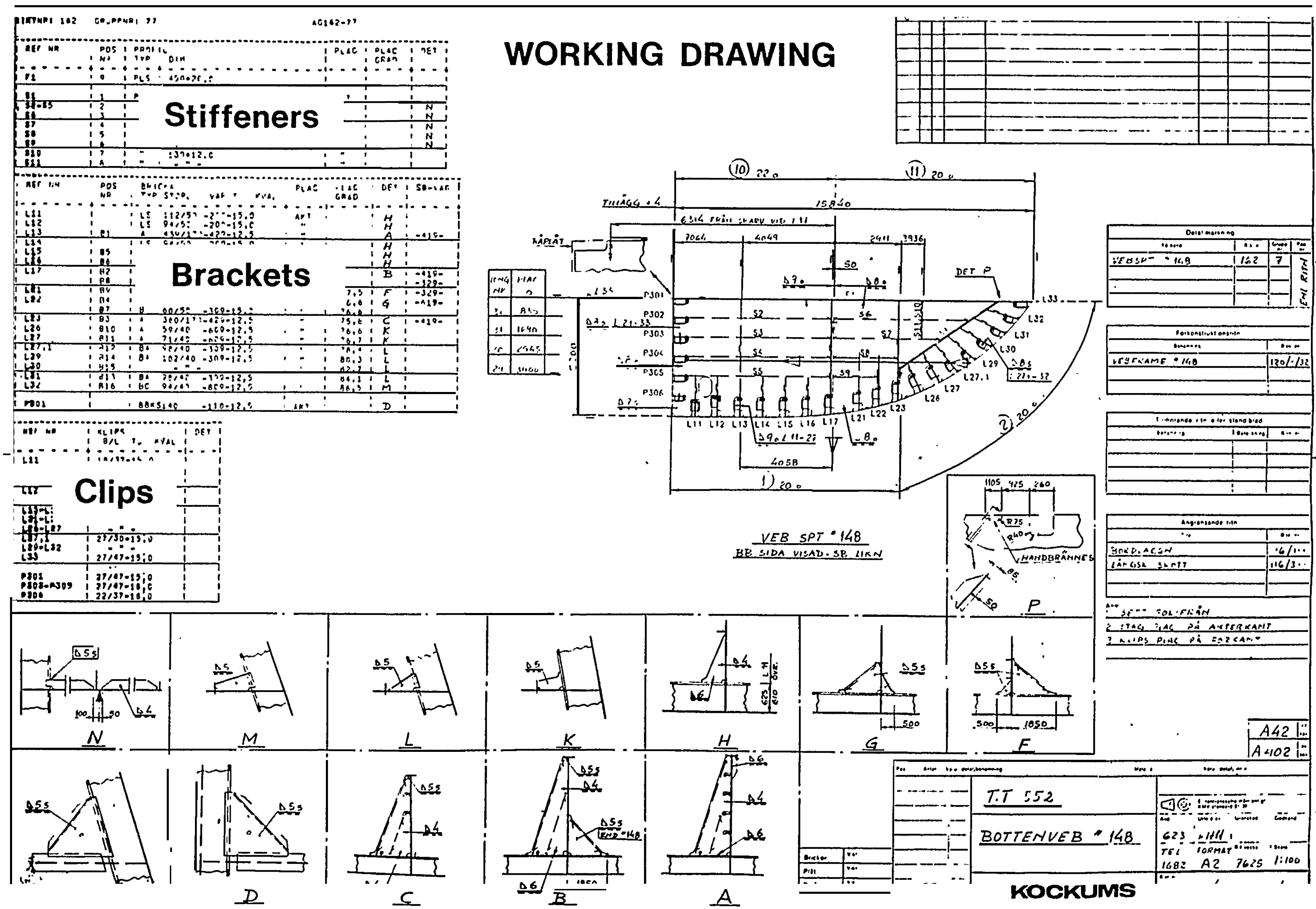
KOCKUMS

Identical panels



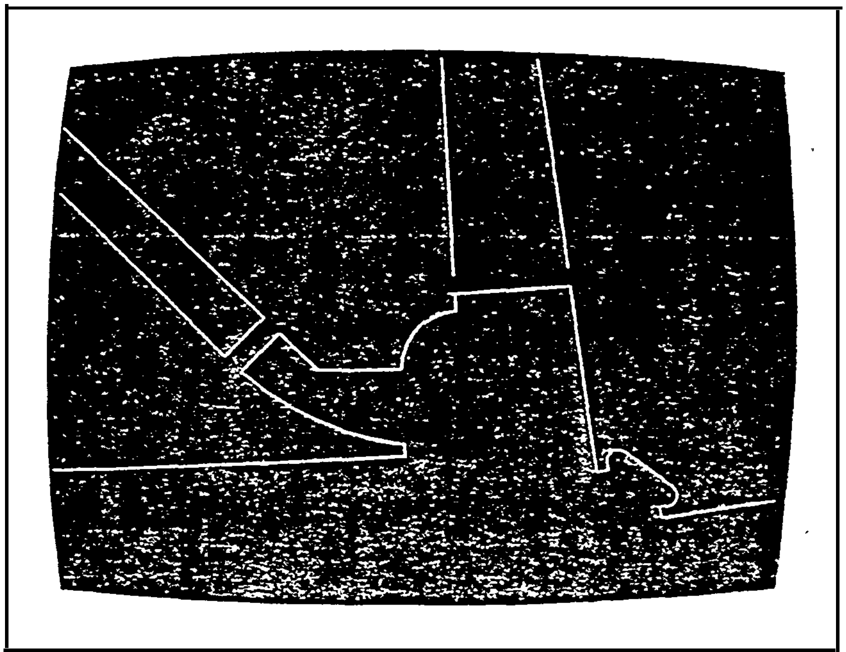
INPUT:

PANEL, ‘B’, ‘C’, EQUAL, ‘A’, X = FR252, FR255;


WORKING DRAWING
Stiffeners
Brackets
Clips
VEB SPT *148
BB SIDA VISAD - SB LIKN
DET P
HANDBRÄNNES
T.T 552
BOTTENVEB *148
KOCKUMS
A42
A402
N
M
L
K
H
G
F
P
D
C
B
A

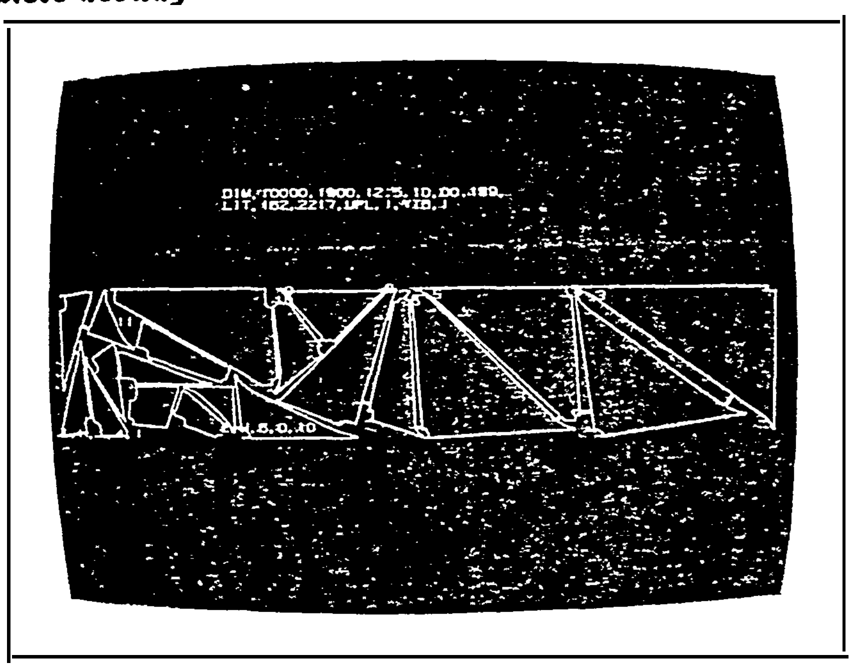
KOCKUMS

Nesting: burning bridges



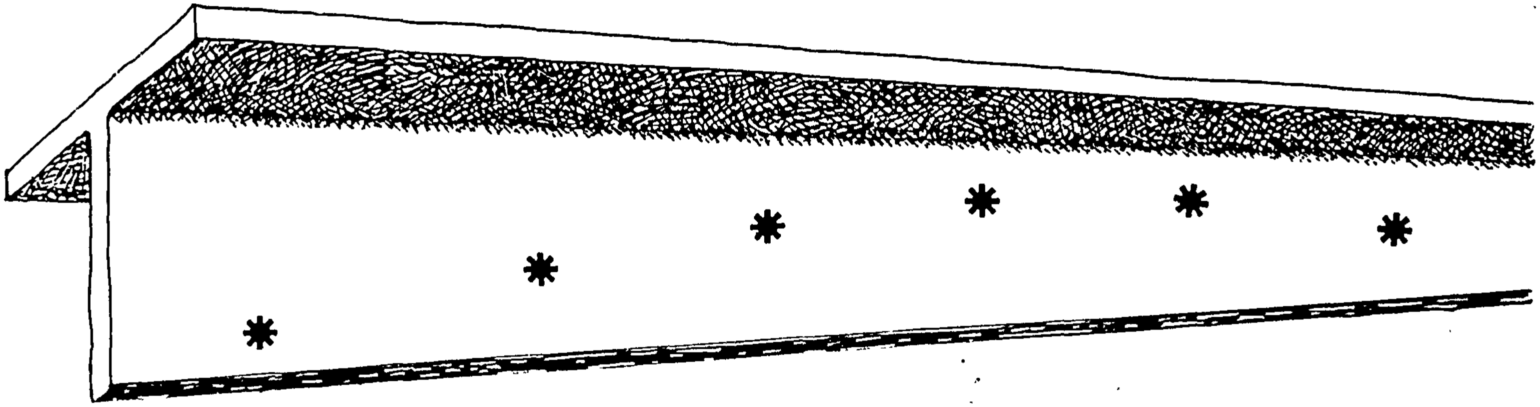
KOCKUMS

Complete nesting



C519

Longitudinal bending table



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KOCKUMS MEKANISKA VERKSTADS AB     MÄRKLISTA FÖR LONGITUDINALER    RITNINGSNR     KALKYLNR  DKNR  VONR    PLE  SID
TS109A                                    1973-09-07               113/10146/-     510-546   113  1131  24202    1

                   / S B  / B B /        /                   X   N   D   K   A   P   S   D   A   T   A
RNR-GNR-LNR  LANGD /DS AS /DS AS/  VIKT /     TYP   MÄRKES       A     B     C   R1   R2     V1   V2   V3    V4    FASL  FASF
=====================================================================================================================
131-1-4       8800 /-- -- /--  1/  1066 / •1•  31    AKT                      14   75         90,4  30   30  90,0
- - - - - - - - - - - - - - - - - - - - / •2•  31                             14   75         90,0  30   30  90,0
TYP/DIM: 43/660•200•13,5•35,0           /
                   +++++ H Å L +++++
HE150•75     V=53  U=960,1920,2880,3840,5600,6400,7200,8000
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B O C K N I N G S T A B E L L 1

AVST	HUJO	AVST	HUJO	AVST	UUJO	AVST	HUJO
0	459	2500	465	5000	463	7500	4bQ
500	4b2	3000	4b5	5500	462	8000	460
1000	4b4	S500	464	6000	462	8500	459
1500	4b5	4000	464	b9Q0	461	0797	459
2000	4bS	4500	463	7000	461l		

B O C K NINOST A B E L L 2

AVST	HOJO	AVST	HUJO	AvST	HUJD	AVST	HUJO

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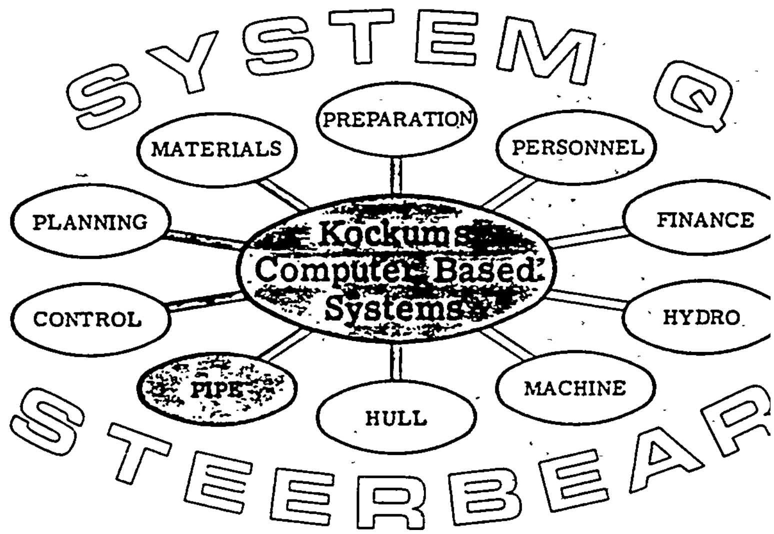


- Simplify and rationalize design work
- Check production restrictions on design automatically
- Minimize manual search in standards file
- Automate pipe sketch production
- Simplify changes in standards and design
- Minimize the manual effort to obtain complete production information
- Automate the calculation of cutting lengths, bending angles etc
- Produce automatically NC-tapes for bending machines
- Simplify sister ship handling

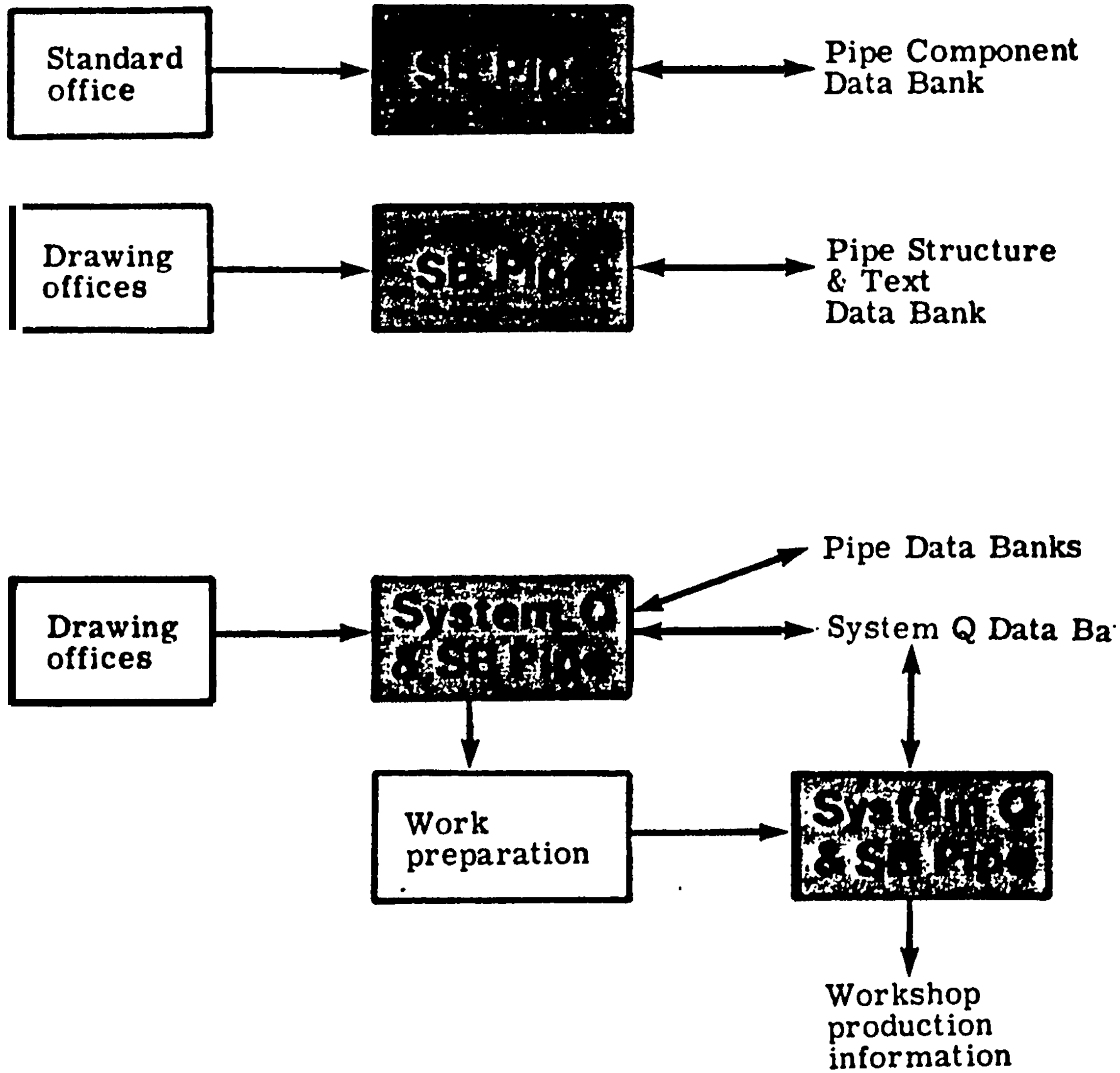
KOCKUMS

STEERBEAR PIPE
— Main Activities

COMPONENT DEFINITION

DESIGN
- Initiation
- Scheme input
- Pipe Geometry Definition

PRODUCTION
- Work preparation information
- Workshop information



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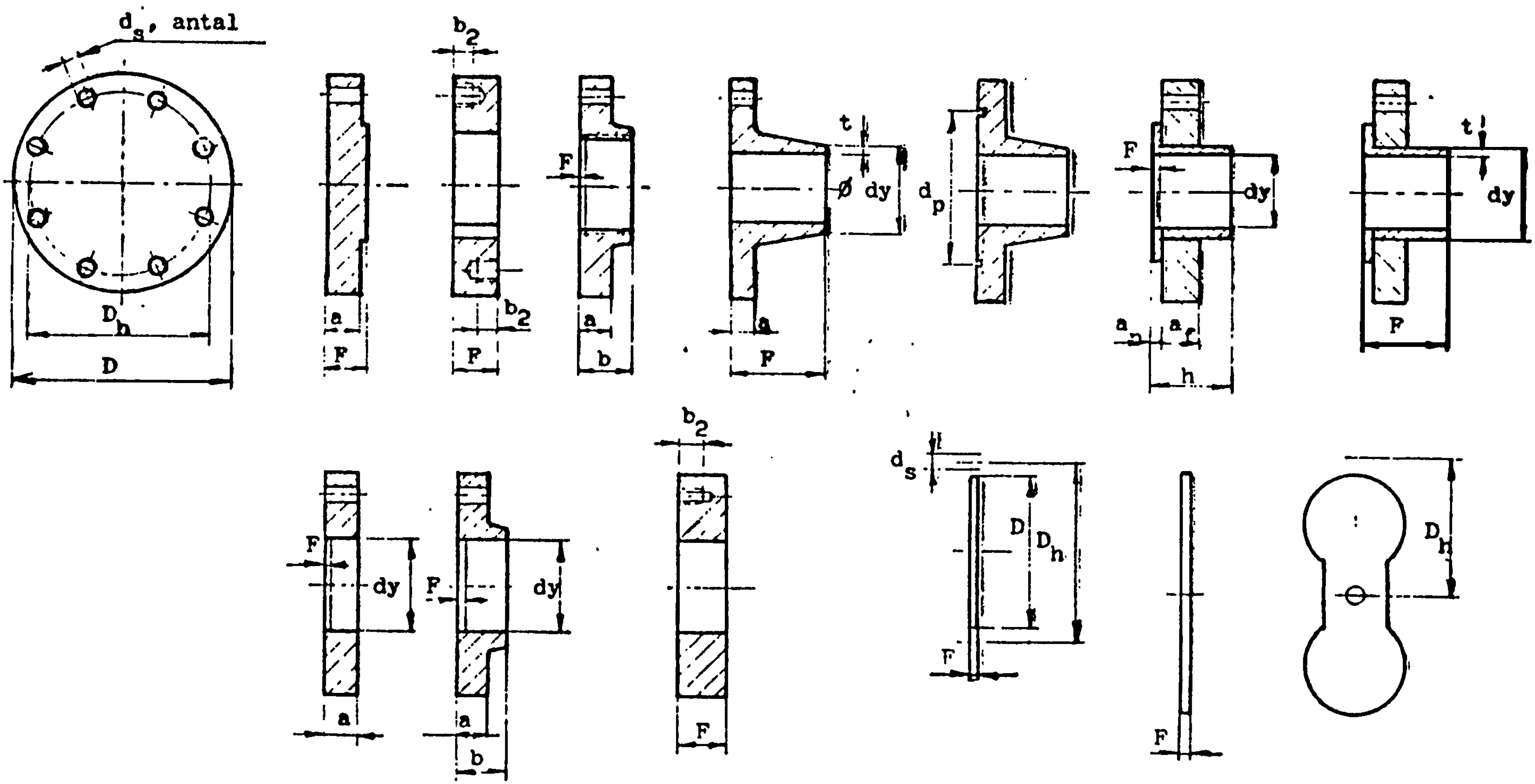
STEERBEAR PIPE
– Stored Flange Standard



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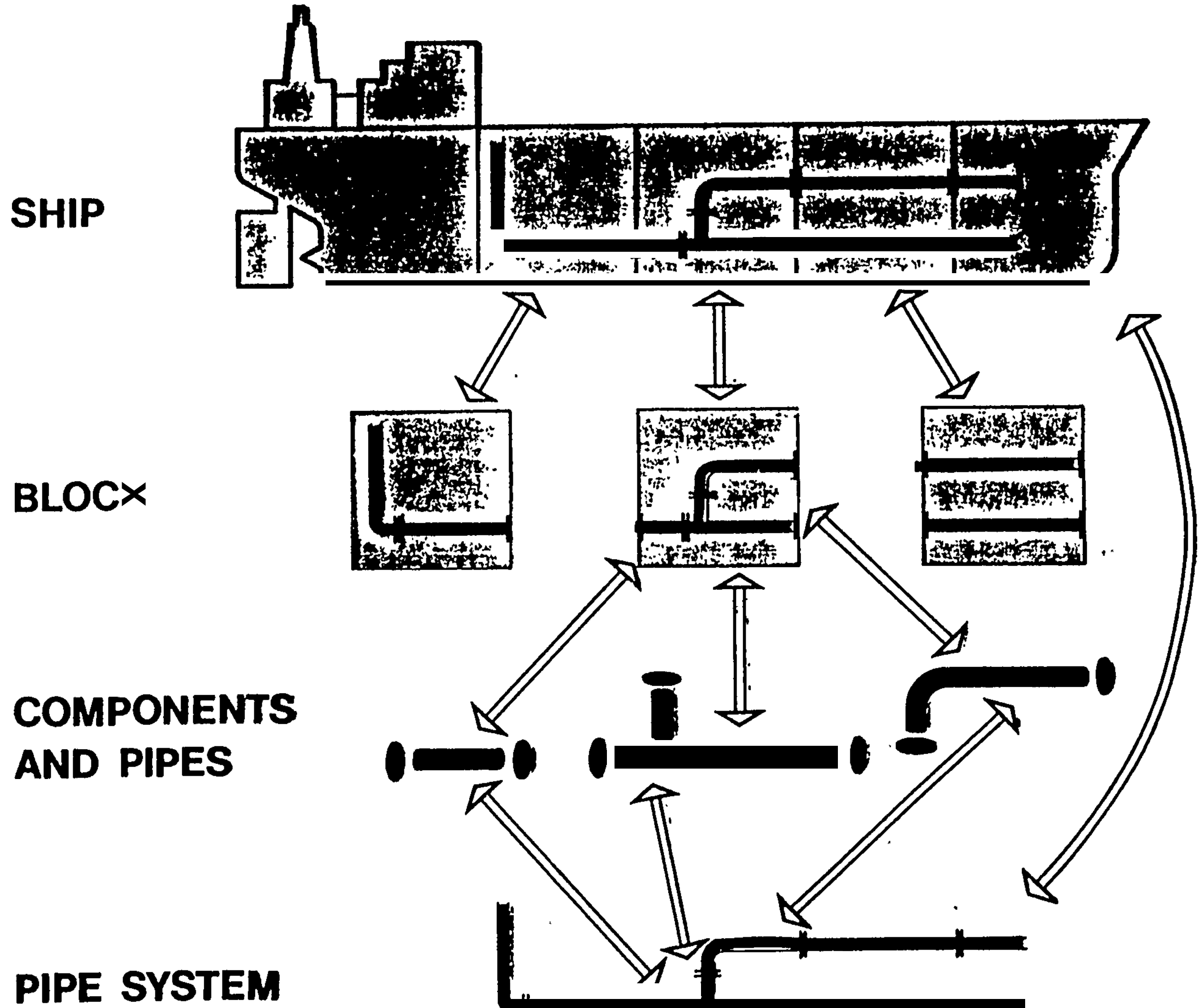
STEERBEAR PIPE
– Data Bank Structure



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STEERBEAR PIPE

—Pipe Scheme Input

LIST OF VALVES AND FITTINGS

Item	Service	Qty	Size	Type	Material	Supplier/Type No	Code	Operation	[illegible]	Notes
V12	Inert gas line waterseal	1	700	[illegible]	Cast iron		205-354541		[illegible] 519	
V13	Inert gas line waterseal	1	700	Butt fly	Cast iron		367-305215	MLO	[illegible] 519	
V15	Inert gas branch line	5	400	Hi-jet	steel		836-323767	MLO	[illegible]	
V16	Inert gas branch line	1	300	Butt fly	Duct iron	JF 9980 N	207-348907	MLO	RN	Kl. 85
V17	Inert gas branch line	5	250	Butt fly	Duct iron	JF 9980 N	207-348908	MLO	RN	Kl. 75

V17	Inert gas branch line	5	250	Butt fly	Duct iron	JF 9980 N	207-348908

- Item
- Service
- Quantity
- Size
- Type
- Material
- Supplier/Type No
- Code

Dept	Syst No	Hull
6 625	HN	510 985

Date	Rev No.	List of valves and fittings	Sheet No	List No.
6-02-04		Inert gas and tank venting system	1 of	831 150814

396

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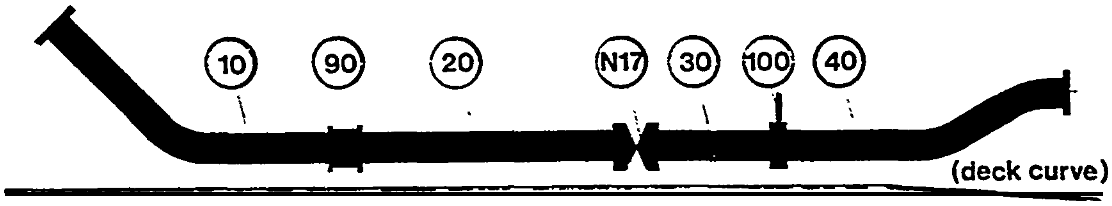
STEERBEAR PIPE
–Pipe Geometry Definition

UHN1- HN1

Position numbers



Component codes

F18	K43	F18	F18	F18
		HNV17	VNR ,233-348733	
		F18	F18	

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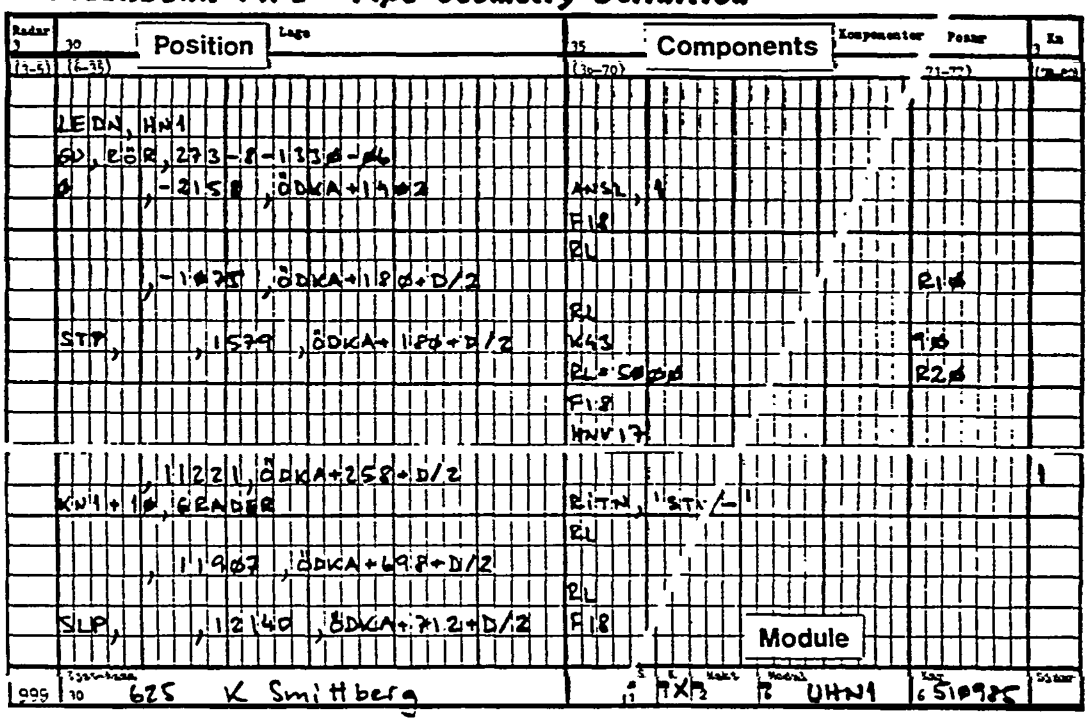
STEERBEAR PIPE –Pipe Geometry Definition



LEDN, HN1
60, RÖR, 273-8-133Ø-Ø6
Ø ,-215Ø ,ÖDKA+14Ø2 ANSL,4
F18
RL
,-1475 ,ÖDKA+118Ø+D/2 R1Ø
RL
STP, ,1579 ,ÖDKA+118Ø+D/2 K43 9Ø
RL+5Ø5Ø R2Ø
F18
HNV17
,11221 ,ÖDKA+258+D/2
KN1+1Ø,GRADER RITN,'STN/-'
RL
,11907 ,ÖDKA+698+D/2
RL
SLP, ,12140 ,ÖDKA+712+D/2 F18
999 10 625 K Smittberg HXB UHN1 6510985

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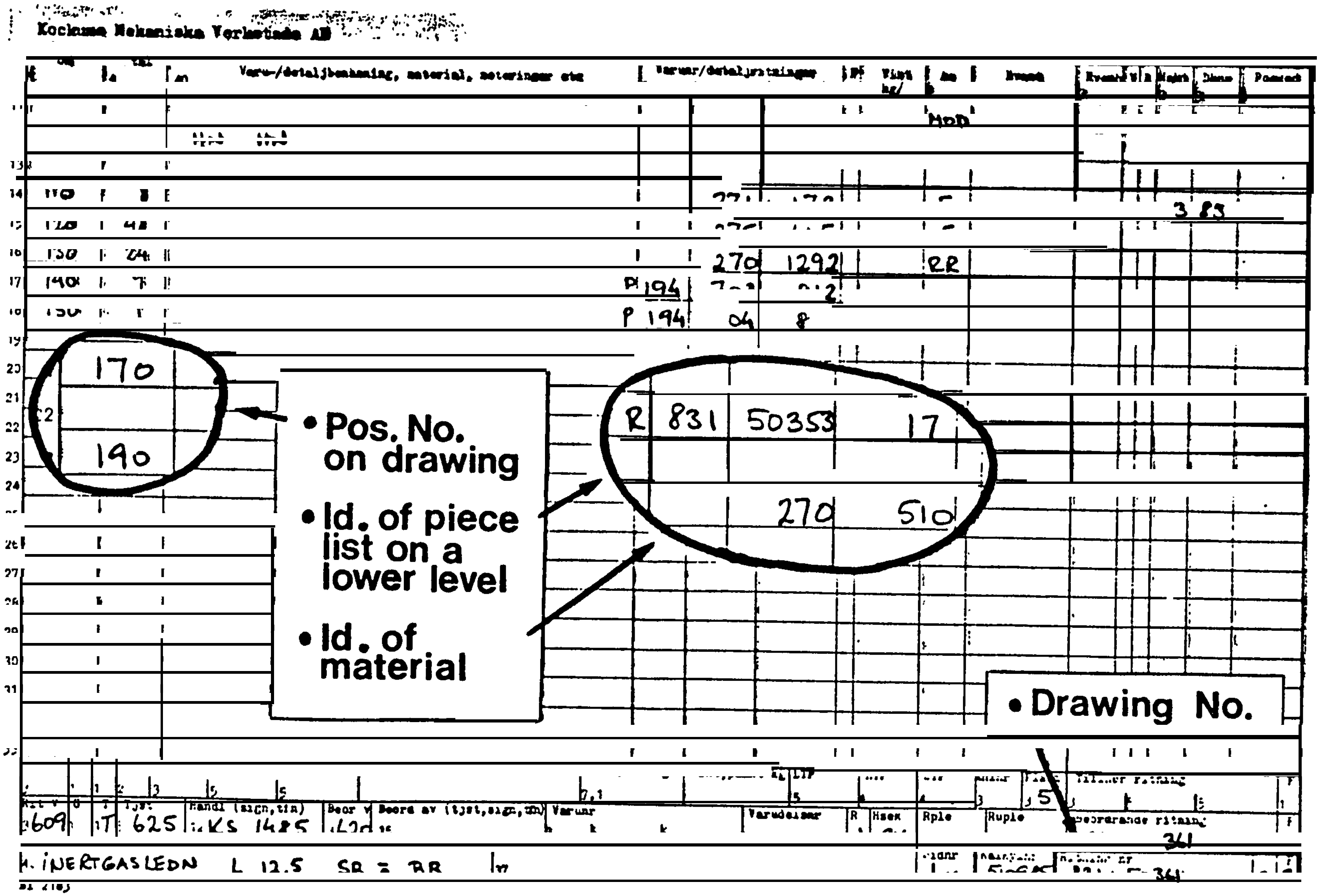
STEERBEAR PIPE — Piece List Draught



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STEERBEAR PIPE
– Pipe Sketch

Pos	Antal	Vara/detaljbenämning	Utför	Vara/detaljbeteckning			Alt	Kvalit	Kvalit	Vikt	Anmärkning
1		RÖR 273X8 STÅL 1330=06 VIS 83 LÄNG	A	00	005	482	L	3773	MM	216	
2	2	PLANFLÄNS NP16 DY=273 STÅL VIS 37-20		00	233	339	L		ST	17	
	1	RÖR 76,1		831	3036	1007					

IST PART

A ---- B ---- C ---- D ---- E

Pkt	Pos	Fog	Svets		Avstånd	Pkt/plan			Rotation	Lum	Kdiag	Kpian	Kproj	Vndn	Detrad	Montaktl
A	2				2606/C										MOT	
B	3				2387/A	B	C	D		91						
E	2				233/D	C	D	E						30		

	AUTOMATSVETS				** EFTERKAP		
PKT	POS	PKT	POS	VINK	**PKT	AVST	
A	2			0,0**	E	233/D	
BOCKNING							
E							
D		-3623	-90,0	30,3	112		
C		350	-180,0	30,0	399		
Pkt	Varning	Frammatn	Vndn	Bestiv	Kproj		

ASSEMBLY PART

Ändring

Ytbehandling	Provtryck MPa	Radie	Typ	Rev	Datum	System	Ritnr	Sektion	Vikt	Benämning	Antal	Sidnr	Kod	Ritning nr
A			242	617	76-08-11		831		25C KG	RÖR 273,0		1	0085	985 UHN 60

APPLICATIONS OF WATER JET TECHNOLOGY TO SHIPBUILDING

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IIT Research Institute
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As Senior Research Engineer, Mr. Labus directs the research activity in the high pressure engineering area including work on high pressure water jetting, ocean engineering, hydraulics and pneumatic systems testing and development, and pressure vessel design and fabrication.

Mr. Labus' past experience includes development of hot-gas hydraulic power units for marine and aeorspace applications; fatigue studies on pressure vessels and pipe lines; actuation control systems for appendage movement on aircraft, miniature power supply systems, and test systems for hydraulic components.

Mr. Labus has a B.S. degree in Aeronautical Engineering from Purdue University and an M.S. degree in Theoretical and Applied Mechanics from the University of Illinois.

INTRODUCTION

The use of hydraulic techniques for ship hull cleaning/surface preparation and cutting of primary metals has received considerable attention in recent years. Water jet cleaning of ship hulls has been investigated and utilized in conventional dry dock operations, but recent results have also shown that it can be used in the submerged condition and has selective material removal capabilities. Cutting of primary metals is a relatively new concept, due to increased capabilities of high pressure equipment. Thin metal sections have been cut and thicker sections can also be cut, but the economics of the process and some technical considerations have yet to be established.

Ship Hull Cleaning

Water jet systems can be used to prepare metal surfaces for initial painting or coating and to remove old coatings or fouling. As with any process there is a set of parameters which affect the overall system performance. Two types of jets have been investigated for the hull cleaning applications: 1) conventional continuous jets, and 2) cavitational jets. Performance of both jets are influenced by the following parameters:

- jet pressure
- nozzle diameter
- cleaning rate
- type of fouling
- standoff distance.

The cavitational jet is strongly influenced by nozzle geometry and standoff distance; while the continuous jet can be substantially

augmented by the use of abrasives, the cavitational jet cannot. The basic difference between the two, jets centers in how the high pressures at impact are generated.. In a conventional continuous *jet,* the pressures are generated by the pump,,whereas in a cavitational jet the pressures are generated when the vapor bubbles, generated in the nozzle, are collapsed at the work surface. Generally, the pump pressure for a cavitational jet is less than that of a conventional jet. The cavitation is generated'in the . nozzle using a standard after body or turning vane configuration. The impact pressures of a cavitational jet can be from 10 to *40* times the pump pressure. Hence, the cavitating jet is an amplification technique. Both jets can be effectively applied in conventional dry dock operations and underwater."

Figures 1 and 2 show conventional dry dock utilization of conventional continuous water jets in the abrasive augmented mode and unaugmented. Both operations are manual using a single lance/nozzle configuration. Multiple nozzle configurations can be utilized but care must be taken to provide adequate reaction of the unbalanced forces. A mechanized system such as the Ruck-Zuck "Dockmaster" [2] carries a bank of jets on an extendable boom and provides the necessary structural support and parameter control to fully realize the capabilities of the jet cleaning system. Obviously in a mechanized system, the power requirements must be substantially higher than in *a* manually operated system, but the productivity is correspondingly greater. Typical production rates for a single nozzle unit range from 800 to 2,000 ft^2/hr with access to the hull being the major influence on the cleaning rate, (This is for marine fouling removal only.) Care must be taken to guard against damage to the hull coating by controlling cleaning rate and standoff_ distance. The foregoing discussion applies to conventional continuous jets only. These systems are commercially available (generally limited to single lance units) from manufacturers such as Aqua Dyne, American Aero, Parteck, etc. with operating pressures to 20,000 psi.

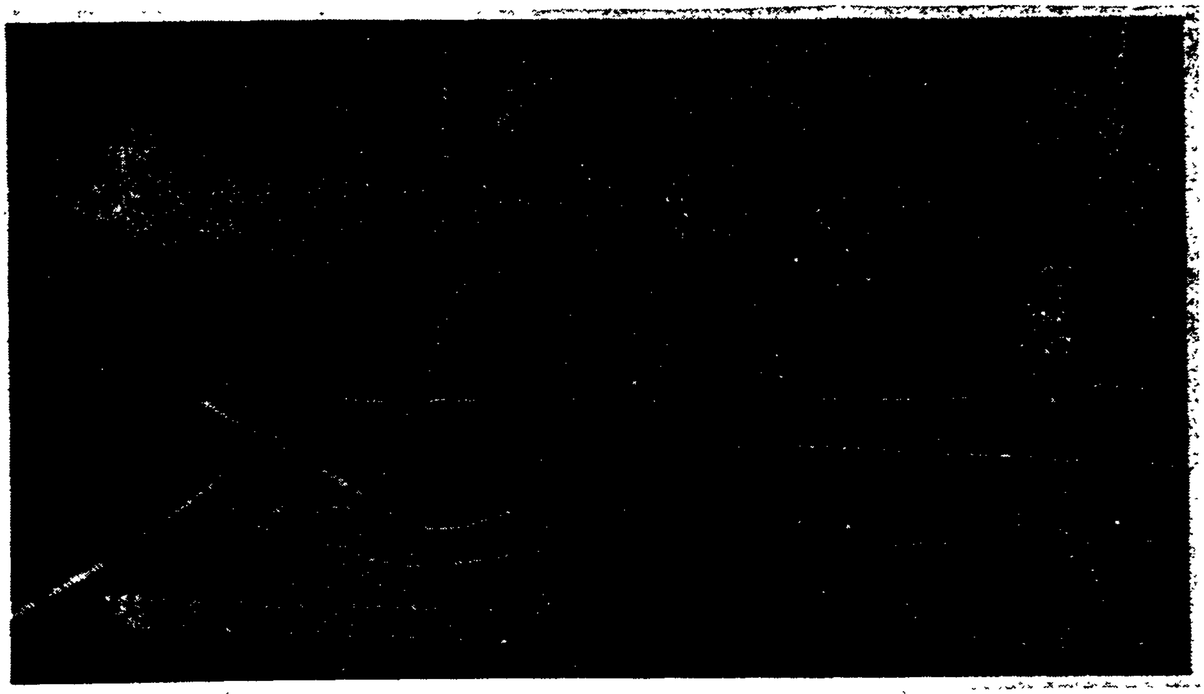

Figure 1. Cutting of marine growth from hull of car ferry showing use of hydraulically assisted jetting guns and extension lances. The operation was completed in 6 hours with two operators using a 120-HP diesel driven pump. (1)

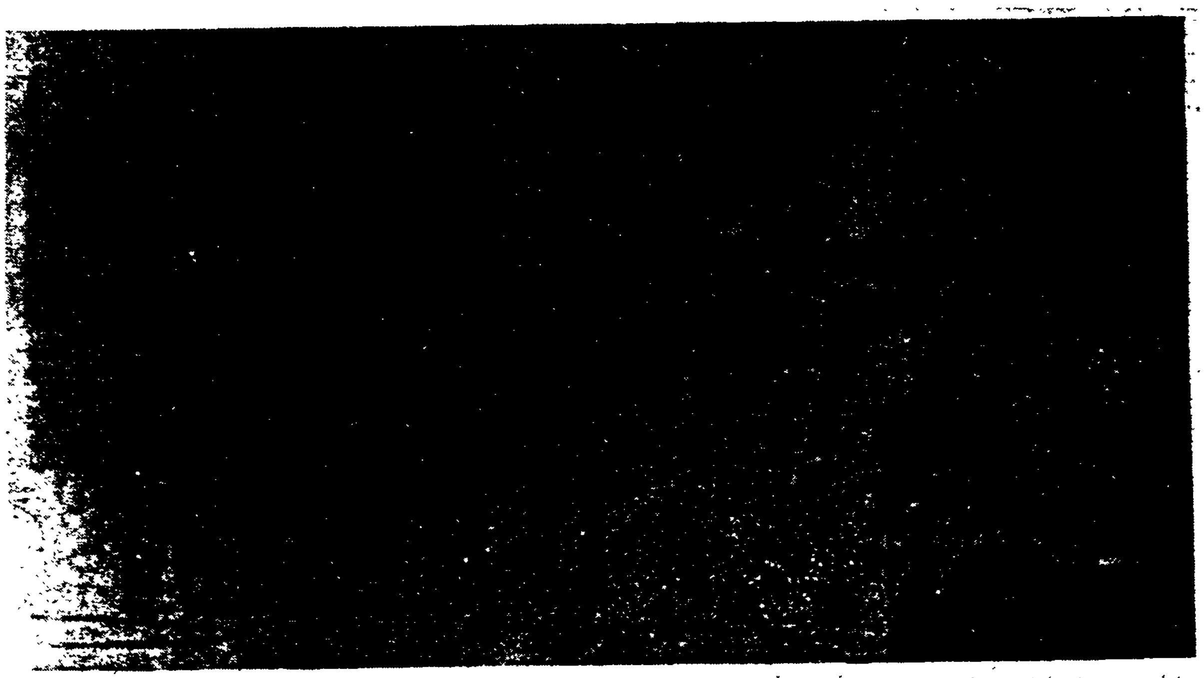

Figure 2. Cutting growth, paint and ferrous scale from hull of tanker using abrasive in water at 4,000 pounds (f)/ sq. in. (1)

As mentioned previously, abrasive injection can substantially enchance the capabilities of the cleaning jet. The abrasive provides an abrading mechanism to handle more difficult jobs than a water-only jet may be able to handle. With the advent of higher pressure systems (20,000 to 100',000 psi) the abrasive may. be eliminated, but ' the decision as to which to use is based on the economics of clean-up requirements and reliability of the abrasive system versus increased capital and operating costs of the higher pressure systems: To inject the abrasive into the jet stream a venturi type of nozzle using the high speed jet to create a vacuum and draw in the abrasive particles is used. By using a combination of water pressure and abrasives, the operating pressure may be reduced or production increased at a fixed pressure level. In comparison of the water-only and abrasive augmented jets the following data [3] apply:

Operating Pressure 6,000 psi (both cases)

> Water-only cleaning of barnacles, rust scale, oil stains, sea grass, were accomplished at the rate of 36.6 ft3/min.
>
> Water-abrasive blasting achieved a white metal surface at the rate of 161 to 194 ft^2/hr. Sand was the abrasive and consumption was 300 to 500 lb/hr[1].

All of the previous results have been for dry dock applications, but water applications have an equal if not greater potential. As stated previously, the operating parameters have a significant impact on the removal capabilities of the jet. Figures 3 and 4 show a damaged and undamaged test plate from which the marine fouling was removed while operating the jet in the submerged condition. From a series of tests (4) it was established that the following combination of parameters produced consistent fouling removal without damage to the antifouling coating for a jet operating in a submerged condition:

- pressure range - 7,000 to 9,500 psi
- nozzle diameter - 0.4 to 0.6 mm
- jet angle > 30° from normal
- translational velocity - 12 in/see.

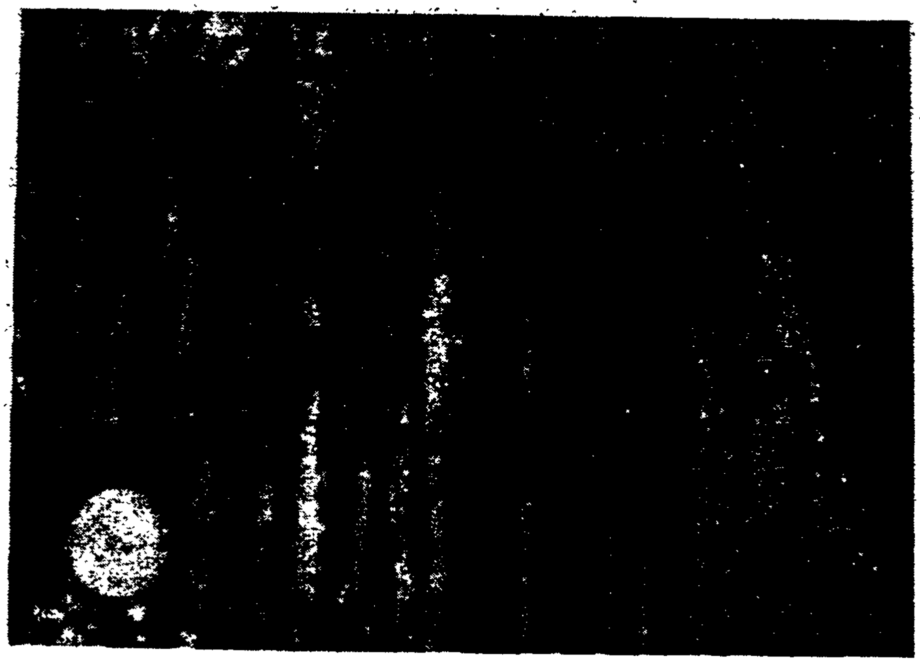

Figure 3. Coated Specimen Damaged y
Water Jet

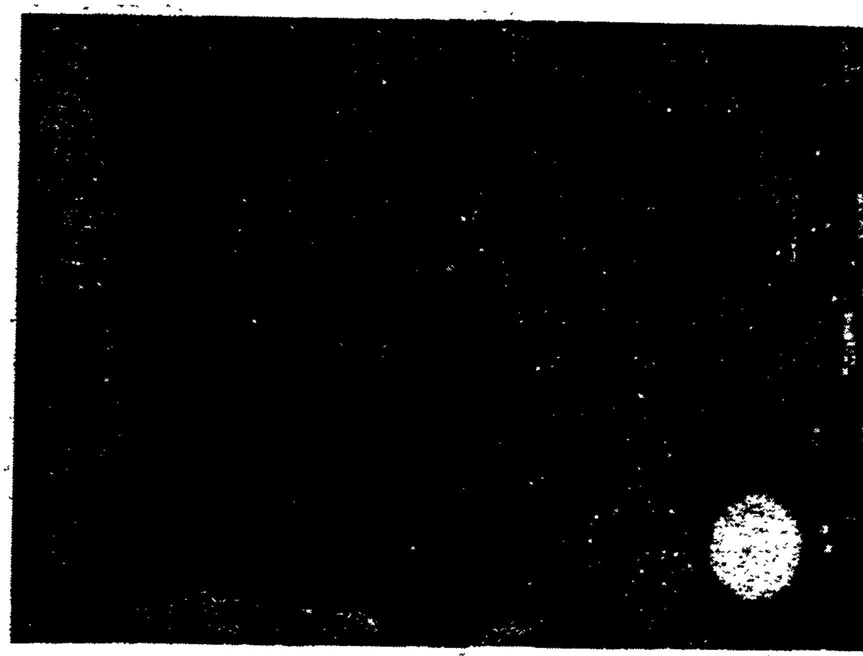

**Figure 4. Coated Specimen Cleaned By
Water Jet**

The jet angle is the most significant of the variables in this case, but it should be emphasized that this combination-of parameters is not an optimum, but a particular combination which. produced acceptable results. If the jet angle is less than” 30°, or the pressure increased while the cleaning rate decreased then damage to the undercoating can result as shown in Figure 3. To successfully implement this technology under water, two problems must be addressed. First, if a single lance unit is employed, then it must be thrust balanced for diver handling, or can be used unbalanced if work platforms are feasible. Second, visibility must be maintained so that the work surface is clear for operator inspection. Visibility can be maintained by using a low velocity jet at right angles to the cleaning jet and tangent to the cleaning surface to disperse the material away from the work area. Another approach would be to mechanize the cleaning operation similar to “SCAMP” whereby visibility is unnecessary and the unit compensates for the thrust automatically. Again, the automated approach will produce greater cleaning rates, but a single lance system would still be required in areas where the hull geometry changes abruptly.

Cavitating jets produce similar results, but at lower pump pressures which should increase the overall reliability of the system. Figures 5 and 6 show before and after photos of a fouled specimen cleaned using a cavitating jet. Note that there is some of the fouling still remaining which indicates too low pump pressure or an improper standoff distance. Figures 7 and 8 show the performance of two different sizes of cavitating jets at two operating pressures. The cleaning rate curves in Figure 8 exhibit classical performance trends. Note that the optimum translational velocity is a function of both pump pressure and nozzle size. The knee of the curves represents the minimum expenditure of energy per unit area cleaned. Operation below this point is inefficient since the dwell time of the jet is longer than necessary to achieve the desired results, while above this point the dwell time is not long enough to produce consistent material removal. (The cleaning rate is equal to the width of the cleaned path times the translational velocity.) The cavitating jet can be used both

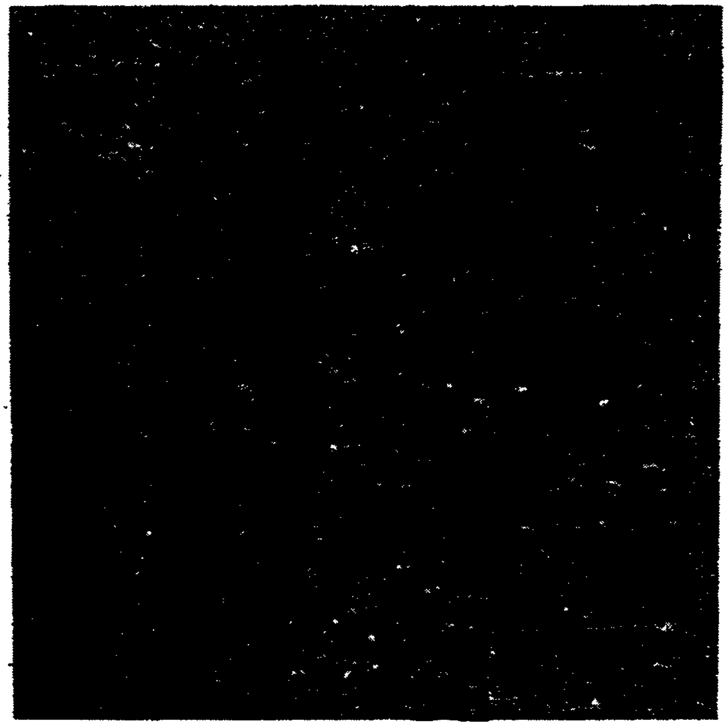

Figure 5. Plate 1, side A before test (5)

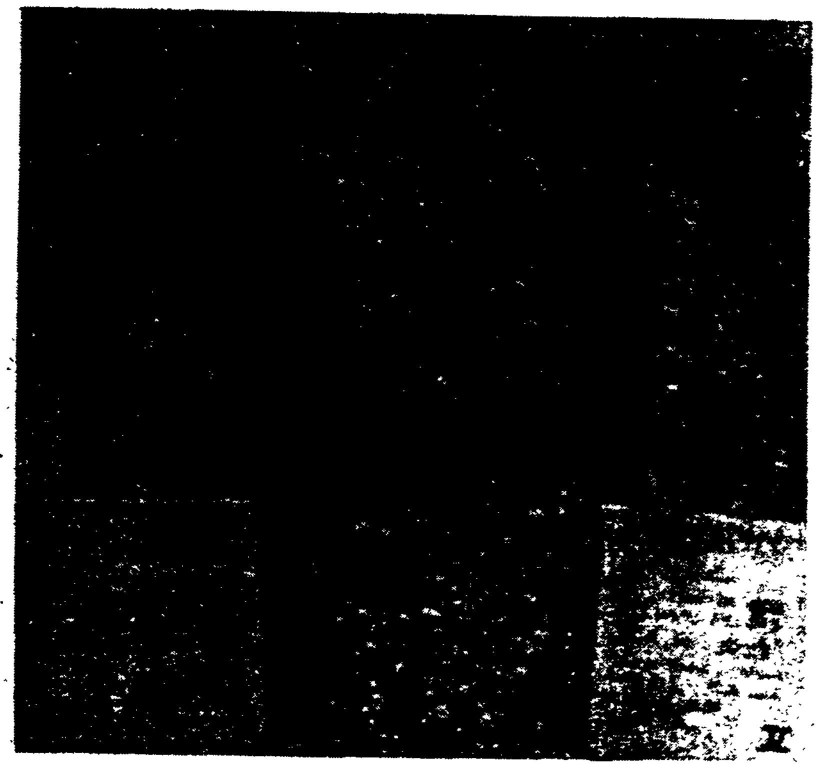

Figure 6. Fouled panel tested with 1/4 in. CAVIJET at 1500 psi (10.3 MPa). (5)

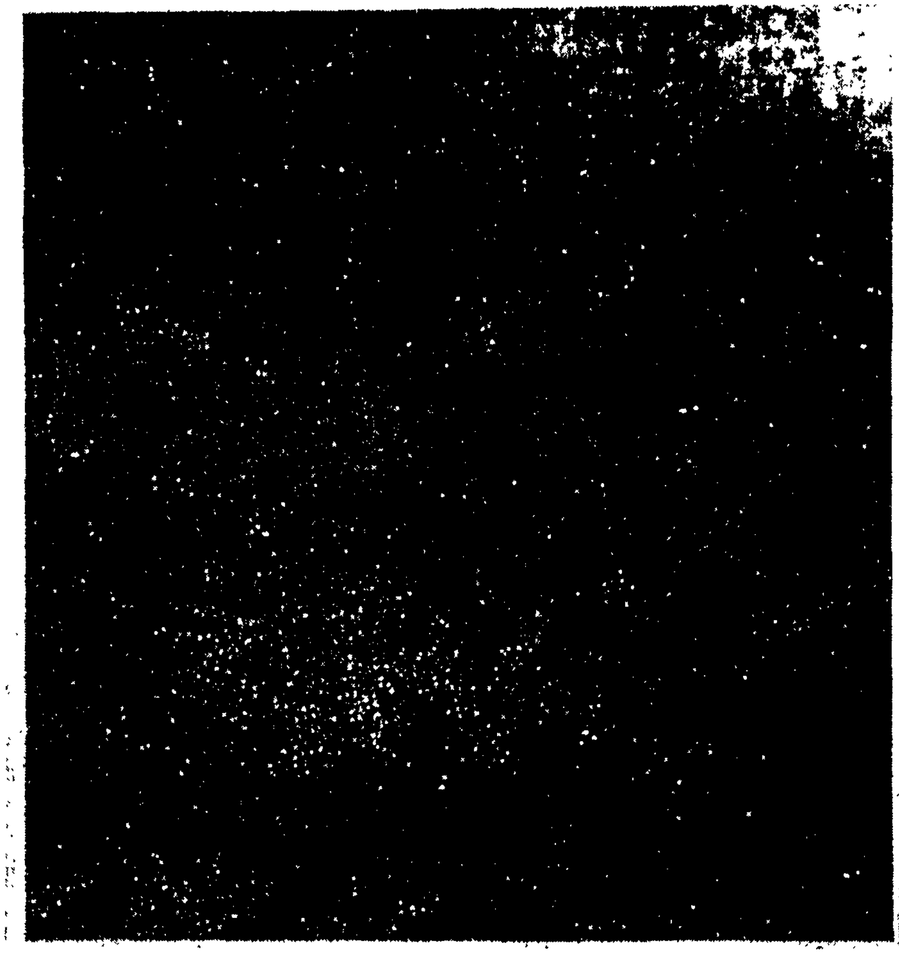

Figure 7. Comparing average fouling removal path widths of 1/8 in. (3.2 mm) and 1/4 in. (6.4 mm) CAVIJET submerged (5)

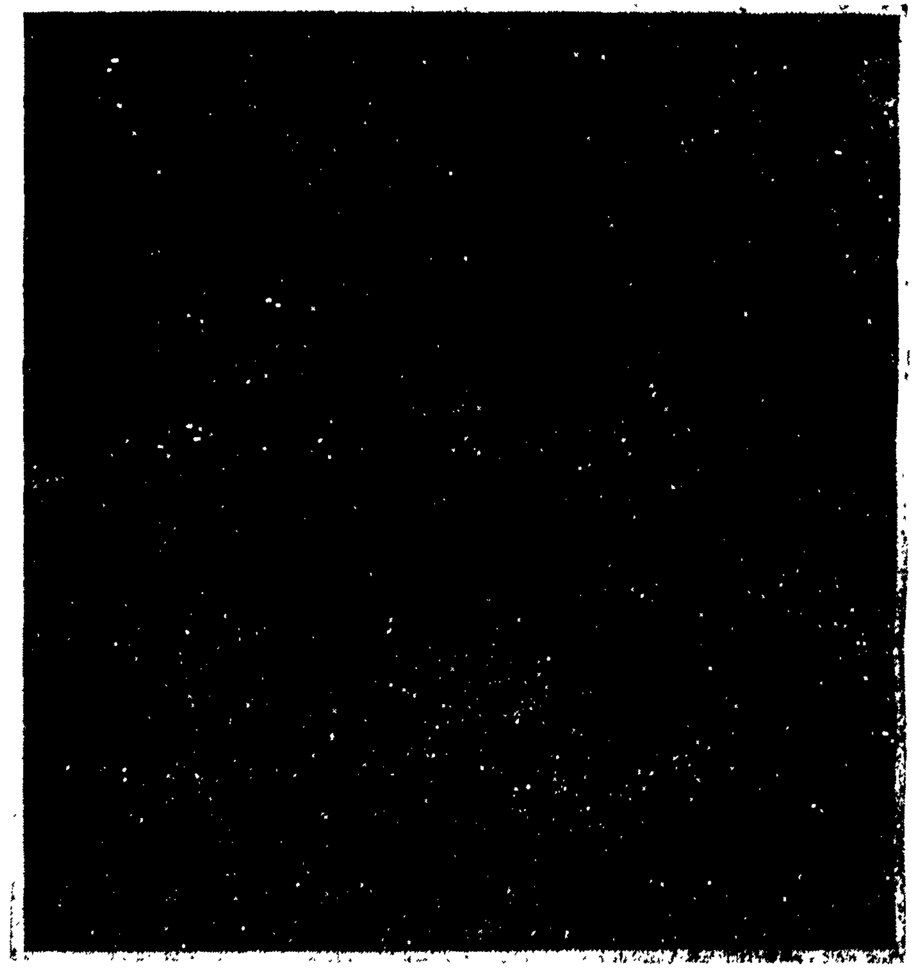

Figure 8. Comparing average fouling cleaning rates of 1/8 in. (3.2 mm) and 1/4 in (6.4 mm) CAVIJET submerged (5)

in dry dock and in the submerged condition. As Figure 9 indicates, it will give better performance in the submerged condition than under ambient conditions. The cavitating jet can be mechanized like the continuous jet, but the standoff distance must be controlled to give consistent results. Table 1 shows some rough economic considerations when using a cavitating water jet as opposed to " conventional practice. Performance (projected) is equivalent, (or better)to conventional practice and the preliminary costs seem attractive. Before an accurate costing of hydraulic removal can . be made, a system must be configured for a particular application so that direct costs (capital, operating, etc.) and indirect costs (loss due to down time, change-over costs, etc.) can be established and included in the analysis.

Based on the data presented, hull cleaning and surface preparation seem to be a natural application in which to utilize fully the capabilities of the fluid jet.

Metal Cutting Studies

The use of high pressure water jets to cut and remove metal is in the embryo stage. Initially it was postulated that to cut a' material of a given tensile or compressive strength a jet pressure of approximately 3 times the strength level would be required. During preliminary work[4] it was established that material could be removed at pressures. as low as 60,000 to 80,000 psi. To achieve these elevated pressures, conventional plunger pumps which were suitable for cleaning use are not appropriate. A linear intensifier as shown in Figure 10 provides a means of achieving these pressures. This particular unit is hydraulically driven (primary power package is not shown) and capable of 100,000 psi and 3.5 GPM output. The same jet parameters which controlled the cleaning process also influence metal removal. As shown in Figure 11, shallow depth cuts have been achieved for a single pass (material is 1020 steel). In its present configuration the jet is suitable for thin sections unless multiple passes are made. High strength ship hull material (HY80) can also be cut using the jet. These test results are for submerged conditions.

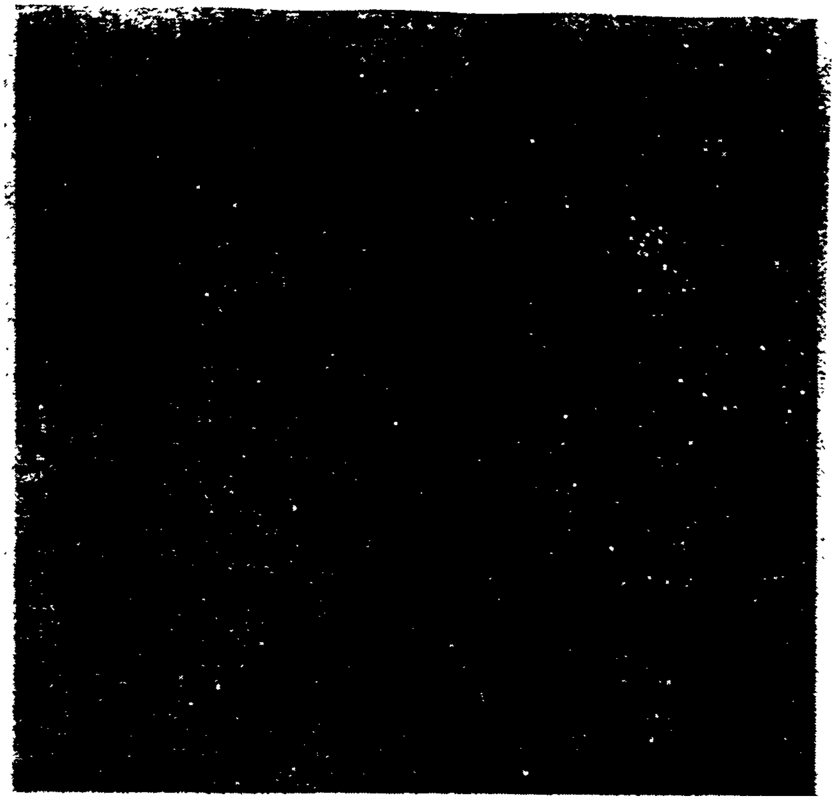

Figure 9. Effect of operating mode on path width for 1/4 in. (6.4 mm) CAVIJET at 2000 psi (13.8 MPa) (5)

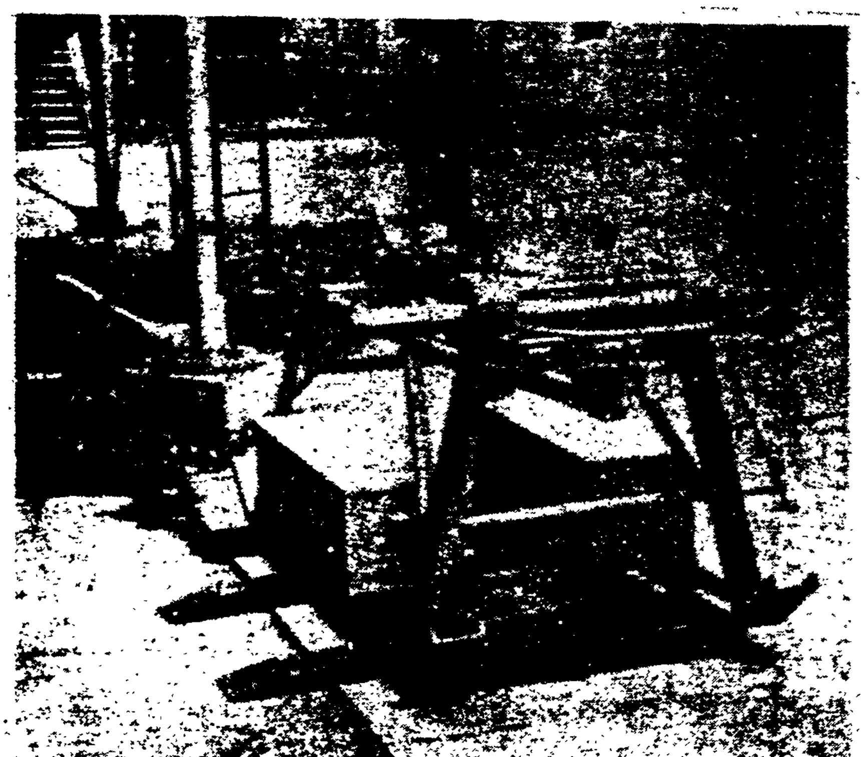

Figure 10. High Pressure Linear Intensifier

TABLE 1

COMPARISON OF HULL CLEANING TECHNIQUES (6)

METHOD	RATE OF CLEANING	OPERATING COSTS	ADVANTAGES	DISADVANTAGES
Wet Sandblasting	* 270 ft^3/hr.	Not Provided	Operational and accepted practice; will provide white metal finish.	Expense of "sand" material; cleanup; water pollution.
Hand-held Rotating wire brushes	* 400 ft^2/hr.	Not Provided	Use on submerged or dry-docked hulls	Slow; will not remove rust
Dry Sandsweeping	*1000 ft^3/hr	* $28/1000 ft^3 for "sand" (slag), plus power, and labor for operating and cleanup	Fast; accepted practice; (At much slower rates: will provide white metal finish)	Expense of "sand" material; cleanup; must shield off other areas of ship; air and wate pollution
1/16" dia. CAVIJET at 1000 psi, 2.4 gpm, 1.4 hp	900 ft^3/hr	2¢/1000 ft^3 for power to the pump motor plus operating labor	No pollution from "sand"; rates comparable to sandsweeping; no expensive removal of "sand" after the job; Usable on submerged or nonsubmerged surfaces; lower pressures and higher efficiencies than ordinary steady water jet methods	Not accepted practice; further development needed to achieve operational system
1/4" dia. CAVIJET at 500 psi, 30 gpm, 9 hp	1500 ft^3/hr	13¢/1000 ft^2 for power to the pump, plus operating labor		

$: The sources for these data are private communications with various shipyar"d and Navy personnel.

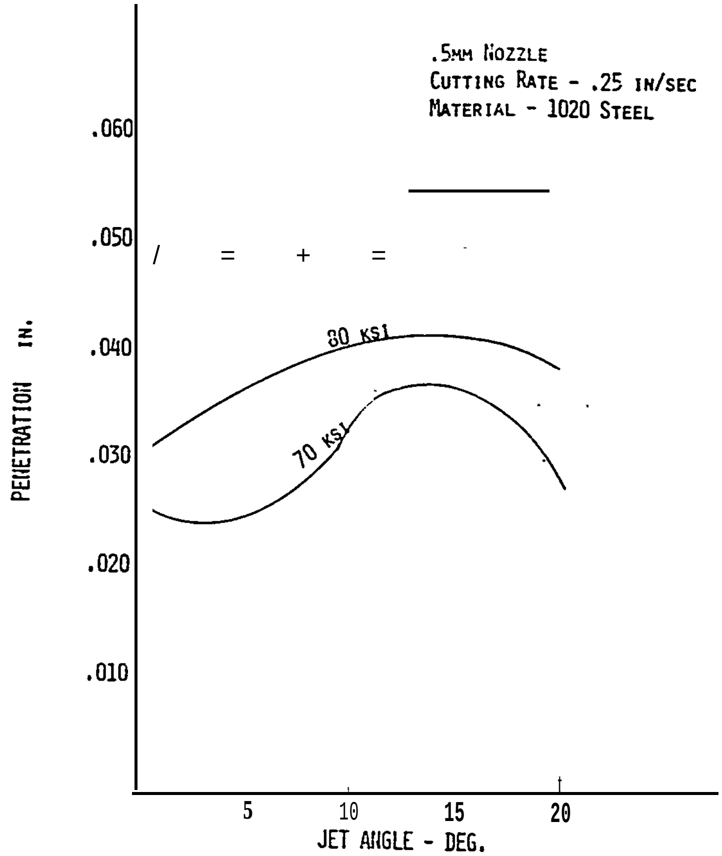

Figure 11. penetration vs. Jet Angle At Various Pressure Levels for 1020 Steel.

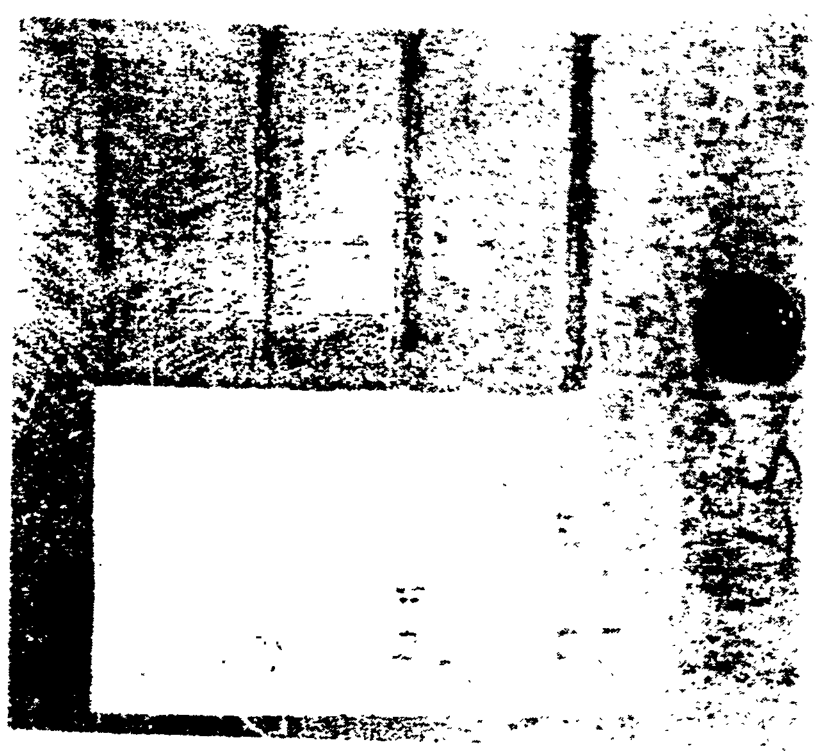

Figure 12. Metal Specimens (1020) attacked by Abrasive Jet.

Abrasive injection was investigated as a means of enhancing the material removal capabilities of the jet. Preliminary results produced penetrations greater than the water-only jet but not as deep as originally projected. Figures 12 and 13 show some results using the abrasive jet. During the testing it was noted that the area surrounding the cut had a shot blasted appearance, and upon examination of some high speed movies of the nozzle flow it was observed that the abrasive particles were concentrated mainly on the outside of the jet stream. Only a small percentage of the particles were in the core of the jet, which would explain the shot blasted area and small increase in total penetrations. A second approach of using a small supplemental high pressure injection pump to inject the abrasive before the nozzle is being evaluated. Preliminary results produced still further enhancement in the penetration, but the testing is not yet complete.

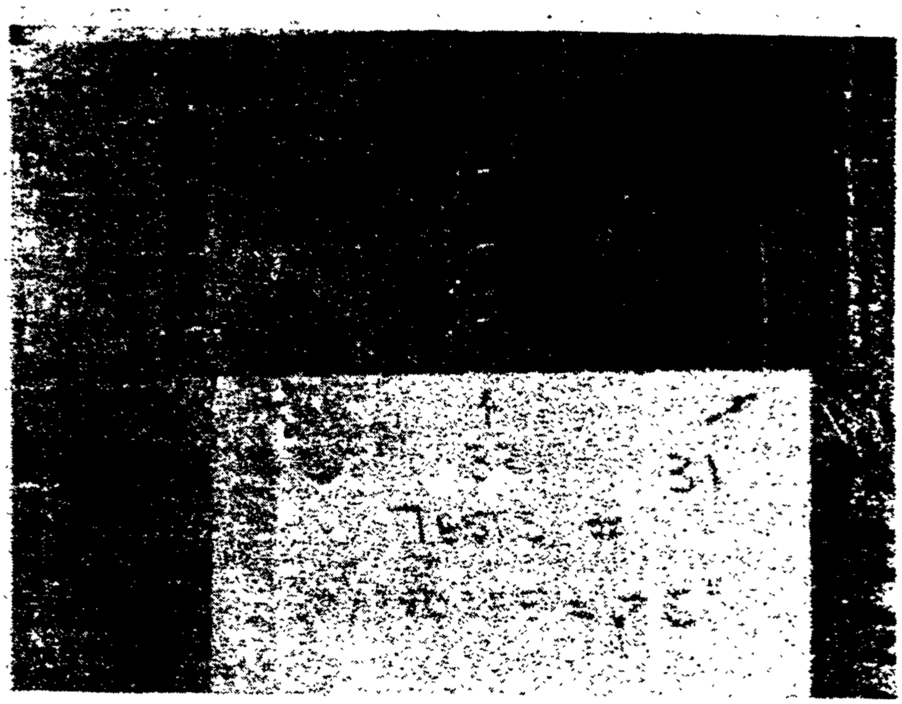

Figure 13 Metal Specimen Attacked by Abrasive Jet.

Heavy steel sections (3/8 in. to 5/8 in.) can be fully penetrated in a matter of milliseconds using a pulsed jet. This

will be necessary for successful application of this type of jet to metal cutting. The effect of underwater operation on this jet is not known at this time.

Conclusions

The use of continuous jets, both conventional and cavitating for hull cleaning and surface preparation provides a viable alternative to conventional methods currently in use. Grit costs can be eliminated and the process can be used in conventional dry dock operations or underwater. Site pollution can be reduced since no grit is utilized, and if underwater operation is used the contaminates (i.e. , fouling, paint, etc) can be removed by conventional filtration methods (assuming the system is used in a flooded dry dock). Metal cutting development requires additional investigation to establish system performance capabilities and to assess its economic impact.

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2. "Shipbuilding International," Vol. 14. No. 1, May 1971.

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5. Conn, A.F., Rudy, S.L., and Mehta, G.D., "Development of a CAVIJET System for Removing Marine Fouling and Rust," Paper No. G4, Proc. Third International Symposium on Jet Cutting Technology, BHRA Fluid Engineering, Chicago, Illinois, May 11-13, 1976.

6. Conn, A.F. and Johnson Jr., V.E., "Further Applications of the CAVIJET (Cavitating Water Jet) Method," Paper No. A3, Proc. Second International Symposium on Jet Cutting Technology, BHRA Fluid Engineering, Cambridge, England, April 2-4, 1974.

THE APPLICATION OF A CNC FRAME BENDER
IN AN AUTOMATED SHIPYARD

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and
Thomas P. Mackey
Hyde Products, Inc.
Cleveland, Ohio

Mr. Acton is a Senior Industrial Engineer responsible for analysis, planning and follow-up on material handling, abrasive blasting, painting and associated systems. He also has 12 years of “hands on” experience with ships as a naval officer. Mr. Acton has a B.S. degree from Illinois Institute of Technology and a Standard Certificate (equivalent to B.A.) from the American Institute of Banking.

Mr. Mackey is President and General Manager of Hyde Products, Inc. A naval architect and marine engineer, he has been in the shipbuilding and equipment business for 20 years. His M.S.E. and B.S.E degrees tire from the University of Michigan.

INTRODUCTION AND SUMMARY

The CNC frame bender is a machine being developed to utilize a computer controlled method for the cold forming of ship frames, especially large steel beams. The technology being incorporated will: (1) shape ship frames by applying mostly pure bending moment to the members - a four point bending action instead of the conventional three point bending; (2) use computer control with feedback to carry out the bending, including corrections for springback; (3) eliminate out-of-plane deformation by built-in computer routines that correct incipient errors detected during the bending; and (4) straighten beams in both horizontal and vertical planes. The frame bender will handle beams with either symmetrical or asymmetrical cross sections.

Research on the development was commenced by Dr. H.W. Mergler (School of Engineering, Case Western Reserve University, Cleveland, Ohio) and associates D.K. Wright, T. Kitcher and M. Savage, along with various graduate assistants, in August 1972, with an 18-month grant from the National Science Foundation Research Applied to National Needs program (NSF/RANN). Following subsequent grants, including one jointly funded with the Maritime Administration, the project was completed in July, 1976. A bench scale model of the beam bending aparatus (See Figure 1) has been constructed and successfully demonstrated by Dr. Mergler and associates; development and utilization of a full size machine by a shipyard is the next step.

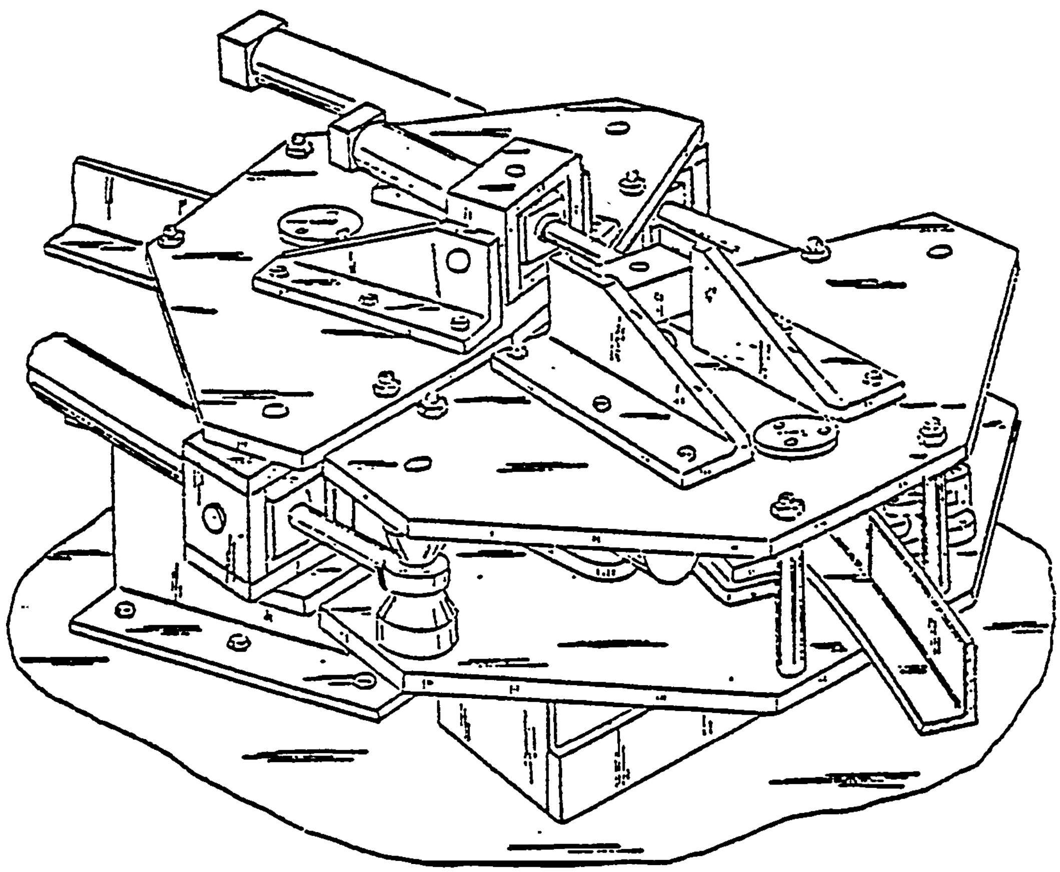


Figure l(a)--Perspective View of the Model Through Feed Bender

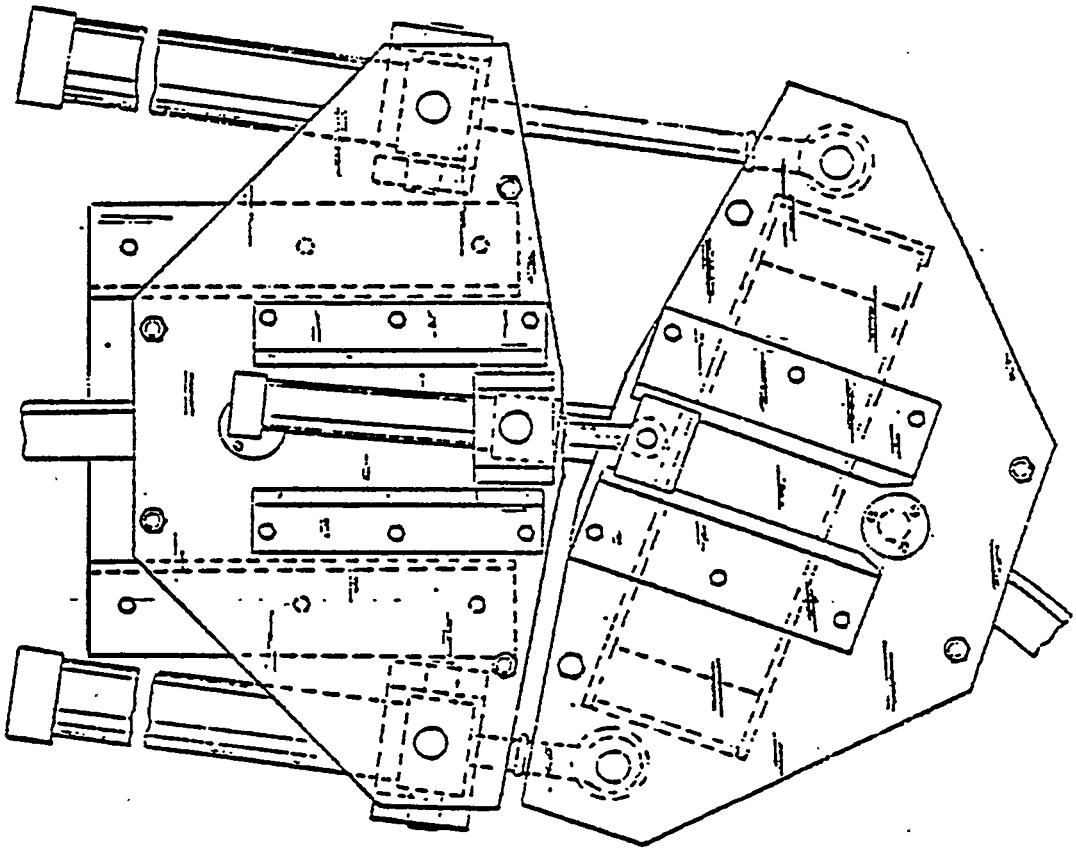


Figure 1 (b)--Top View of the Model Bender

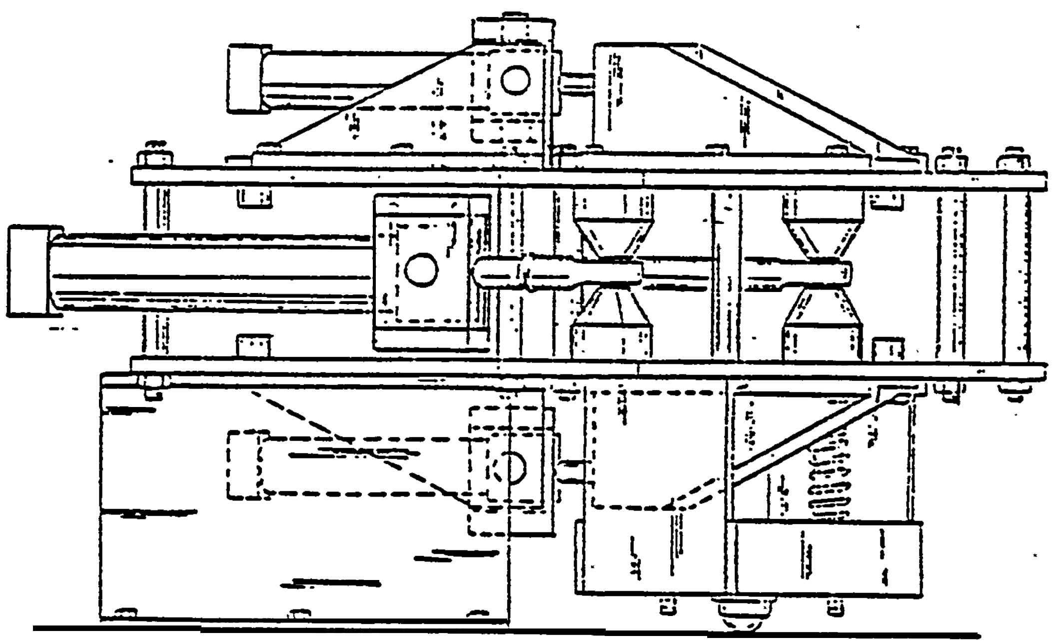


Figure 1 (c)--Side View of the Model Bender

Over the past year, National Steel and Shipbuilding Company has completed an internal analysis of the cost effectiveness of an automated beam bender for their operations, and are convinced that the Case Western bender is the best technology available. Concurrently, the Naval Sea Systems Command, under” the Defense Department’s Manufacturing Technology Program, has evaluated the Case Western beam bender as a candiate for their . support; their plan is to fund the building of a full scale model which NASSCO will use as government furnished equipment. Contract negotiations are currently in process with a goal of an operational machine by mid-1$179. Hyde Products Inc., a subsidiary of Zimmite Corporation specializing in custom machine design and construction, has been granted an exclusive license to market the Case Western beam bender and will be the manufacturer of the machine.

NASSCO FRAME BENDING REQUIREMENTS

NASSCO has developed a method of shipbuilding utilizing fabricated angles and tees (frames) which permits the use of different thicknesses of metal for web and flange and which results in greater strength with lighter weight at less cost (see Figure 2). These frames are cut from flat plate on the flame planner and transported by conveyor to the automatic "tee-welder" where they are welded. Maximum size is 40' in length with a 25" wide x 1/2” thick web and 8" wide x 1“ thick flange. The welding process results in deformation of the frame and although annealing torches are applied to the edges of web and flange to minimize this effort, about 95% of these frames require straightening before use

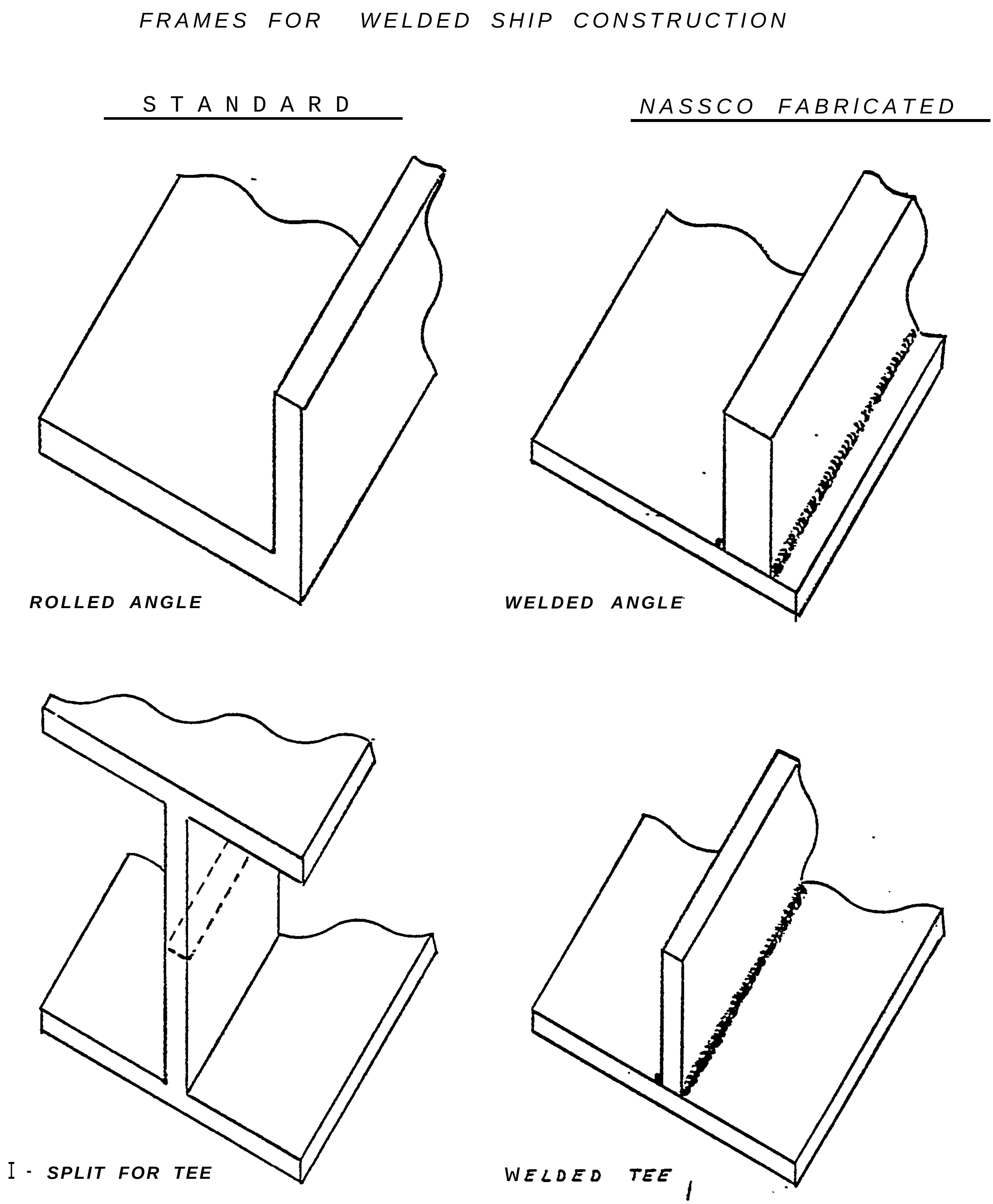

FRAMES FOR WELDED SHIP CONSTRUCTION
STANDARD
NASSCO FABRICATED
ROLLED ANGLE
WELDED ANGLE
I - SPLIT FOR TEE
WELDED TEE

FIGURE 2

(see Figure 3).

Most of the shaped frames are bent around the web, which cannot have any wrinkles (see Figure 4). Current facilities are confined to hot forming, using a natural gas-fired furnace. With average labor cost of $152.00 plus fuel cost of $66.00 each, the projected increase in gas rates (see Figure 5), and the potential shortage of natural gas, this method of forming will be increasingly prohibitive. In addition, such heavy use of the furnace results in more rapid deterioration and a higher rate of repairs; in 1975, repair costs amounted to over *$28,000.00.* Another detrimental aspect of hot formed frames is that they change shape slightly during cooling resulting in additional costs during assembly (see Figure 6).

Frames that are installed as straight sections must be free of deformation. In most cases, the deformation is removed on a Cleveland #2, 200-ton capacity straightening and bending machine ("bulldozer") capable of a maximum beam size of 24", horizontal or vertical. Operating at 28 straight- per minute, the frame is beaten until it appears straight to the naked eye. When deformation is in 2 planes, the frame is first straightened in one plane, removed from the machine, the holding fixture changed and the frame straightened in the second plane. One frame costs $11.50 (labor) to straighten. If deformation is around the flange (Figure 3A) and is not too severe, straightening can be accomplished by heating portions of the web with a portable torch. Severe deformation must be straightened using the gas furnace. If the deformation is in the form of a twist (Figure 3D), the straightening operation must be done in the gas

DEFORMATION OF WELDED FRAMES

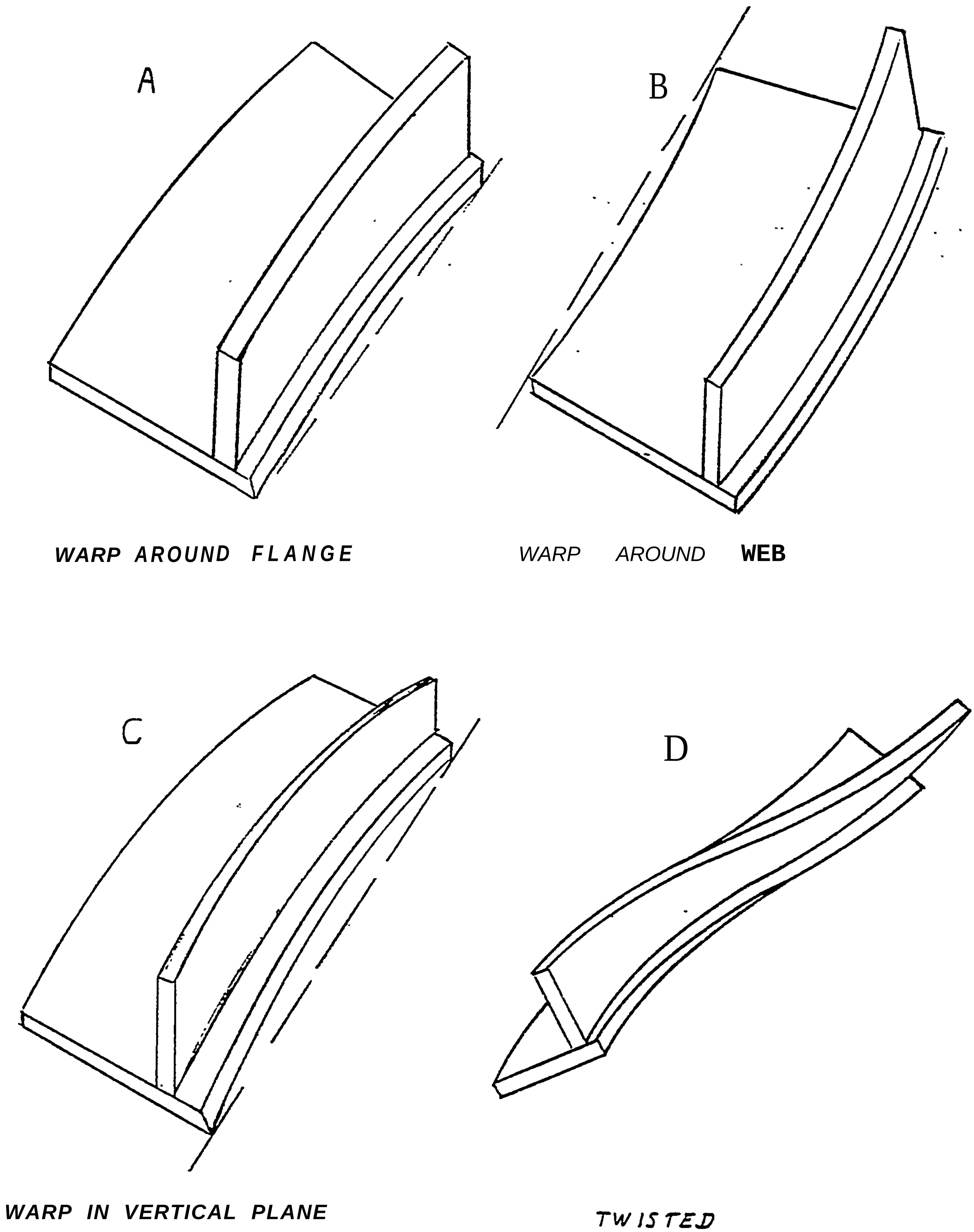


FIGURE 3

WRINKLED WEB

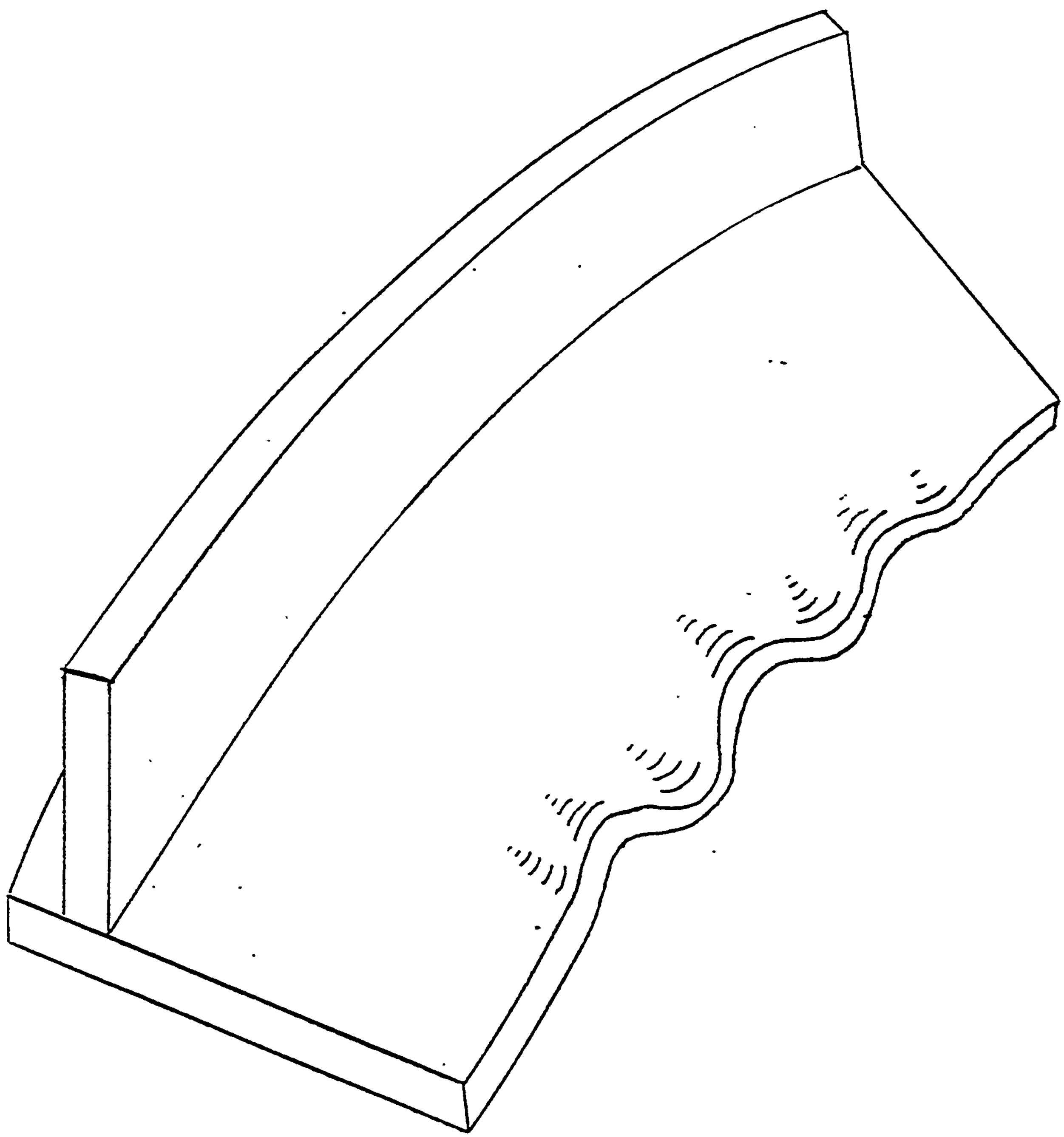
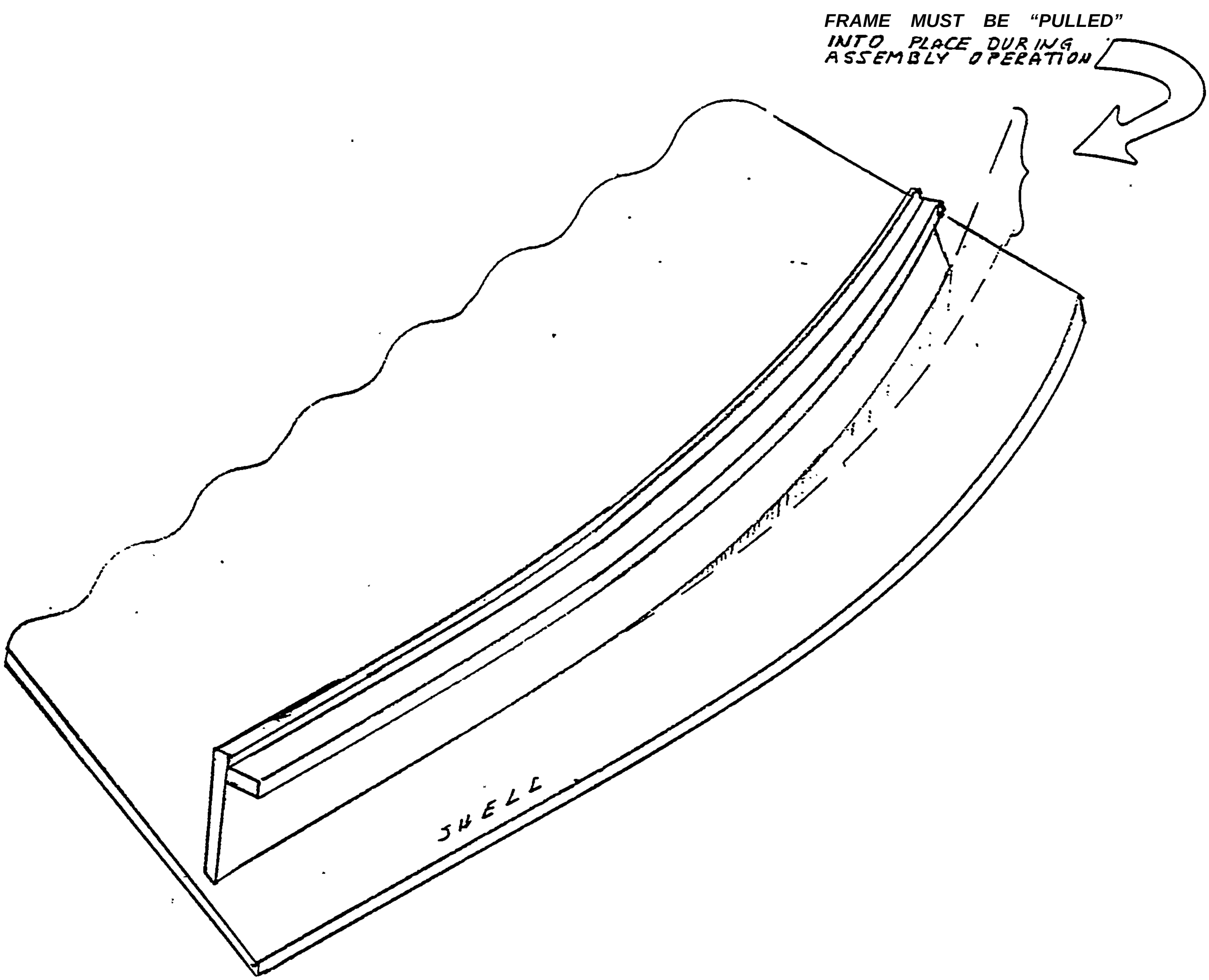


FIGURE 4

COST PER MILLION BTU

	1974	1975	1976	1977	1978
ELECTRICITY	$6.15	$7.91	$12.31	$16.99	$18.75
/KWH	.021	.027	.042	.058	.064
NATURAL GAS	$ .61	$1.10	$2.50	$3.40	$5.10
/THERM	.061	.110	.250	.340	.510
PROPANE	$3.59	$4.13	$5.00,	$5.65	$ 7.07
/GALLON	.33	.38	.46	.52	.65
DIESEL	$1.85	$2.77	$ 2.99	$ 3.56	$3.92
/GALLON	.26	.39	.42	.50	.55

INCORRECT FRAME CONTOUR



furnace. It should be noted that the smaller, lighter-weight tees used on Navy ships distort in more planes and are more difficult to straighten (in the bulldozer) than the heavier angles used on commercial tankers.

FRAME BENDING ANALYSIS

Obviously, any frame bender would improve the situation; however, NASSCO has elected to proceed with the CNC approach and, since commercial beam benders are available, the application of the CNC famebender should be evaluated in relation to the differences between it and those rather than with hot slabbing. Therefore. a brief review of those differences is in order.

The method used by NASSCO to form bent members for ship frames has been to fit each newly bent member to a precut wood template; a number of beam benders use the method of straightening out the inverse of the desired bend, which has been chalked from a template onto the member to be bent. Both methods are trial-and-error and require skillful operators to produce accurate results within a reasonable time. A second, more critical disadvantage of both present systems is the use of a three-point bending method. Such a bend causes large shear stresses and consequently, undesirable twisting and out-of-plane bending; the latter is especially acute in bending beams with asymmetrical cross sections.

The technique developed by Dr. Mergler and his associates at Case Western Reserve University avoids both problems. Their technique depends upon what is essentially a four-point bending action to achieve zero shear force bending over the bulk of the

bend. It relies upon independent control of the plane-of-moment application and feedback corrections in order to avoid out-of-plane deformation.

The forces and moments associated with the two basic bending method are sketched in Figures 7 and 8. The conventional three-point bending produces shear forces throughtout the bent member; the four-point loading achieves zero shear forces (i.e. constant bending moment) along most of the bend, a highly desirable feature in bending.

In pure bending, the beam is gripped at two points and bent exerting pure moment forces on the beam (see Figure 9). In the ideal case, there is zero shear force over the entire length of the beam. Since in the realistic case a finite gripping area is needed, shear forces do exist in this region and the bending is equivalent to four-point bending rather than to idealized pure bending (see Figure 9A).

To minimize the unavoidable out-of-plane deformation experienced in bending beams of asymmetrical cross section when using conventional equipment, the Case Western bender separates the plane-of-moment application from the desired plane of deformation (see Figure 10). In order to avoid out-of-plane deformation, the plane in which the moment must be applied does not coincide with the principal axis of the beam. Thus, to bend the angle beam in the plane of the major web, the moment must be applied in a non-obvious plane (Figure 10). Before bending this beam with the Case Western machine, a calculation of the separation angle between the two planes is made and once the bending is underway , corrections in the separation angle are made as needed to eliminate out-of-plane deformation. Since conventional beam

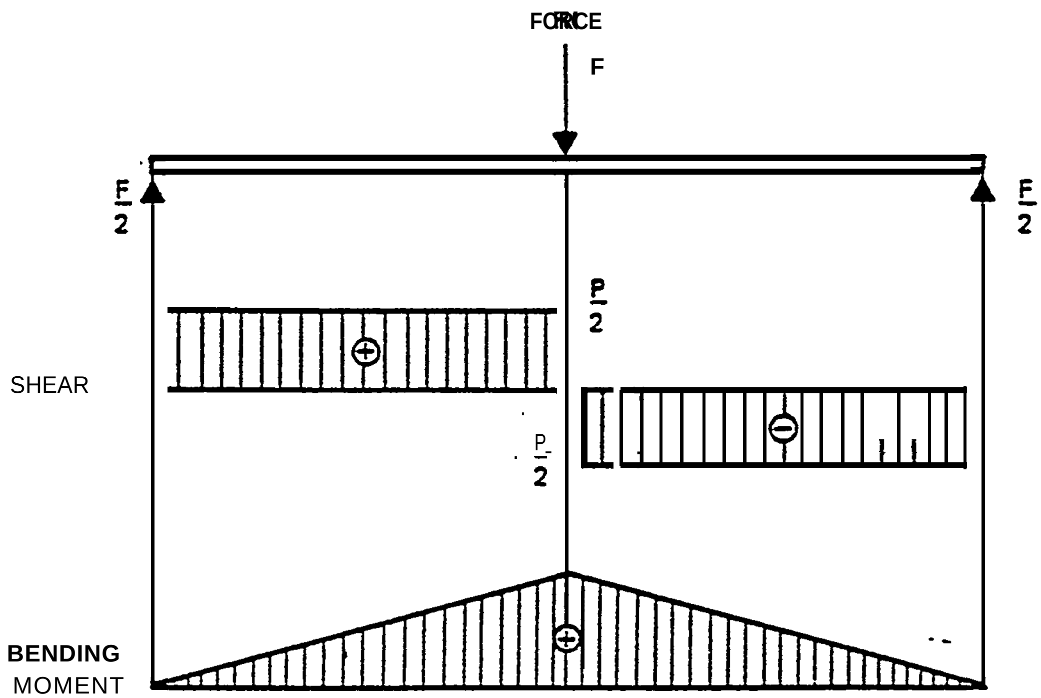


Figure 7 . Traditional Three-Point Bending.

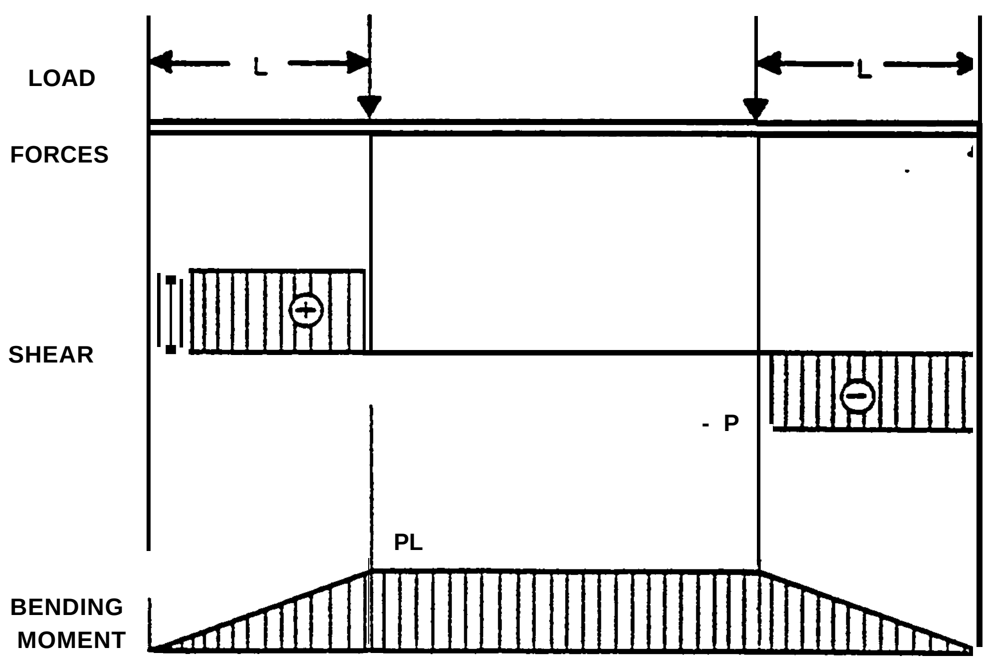
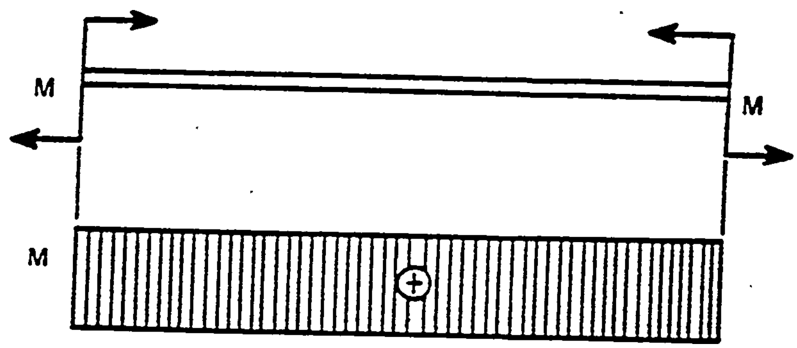
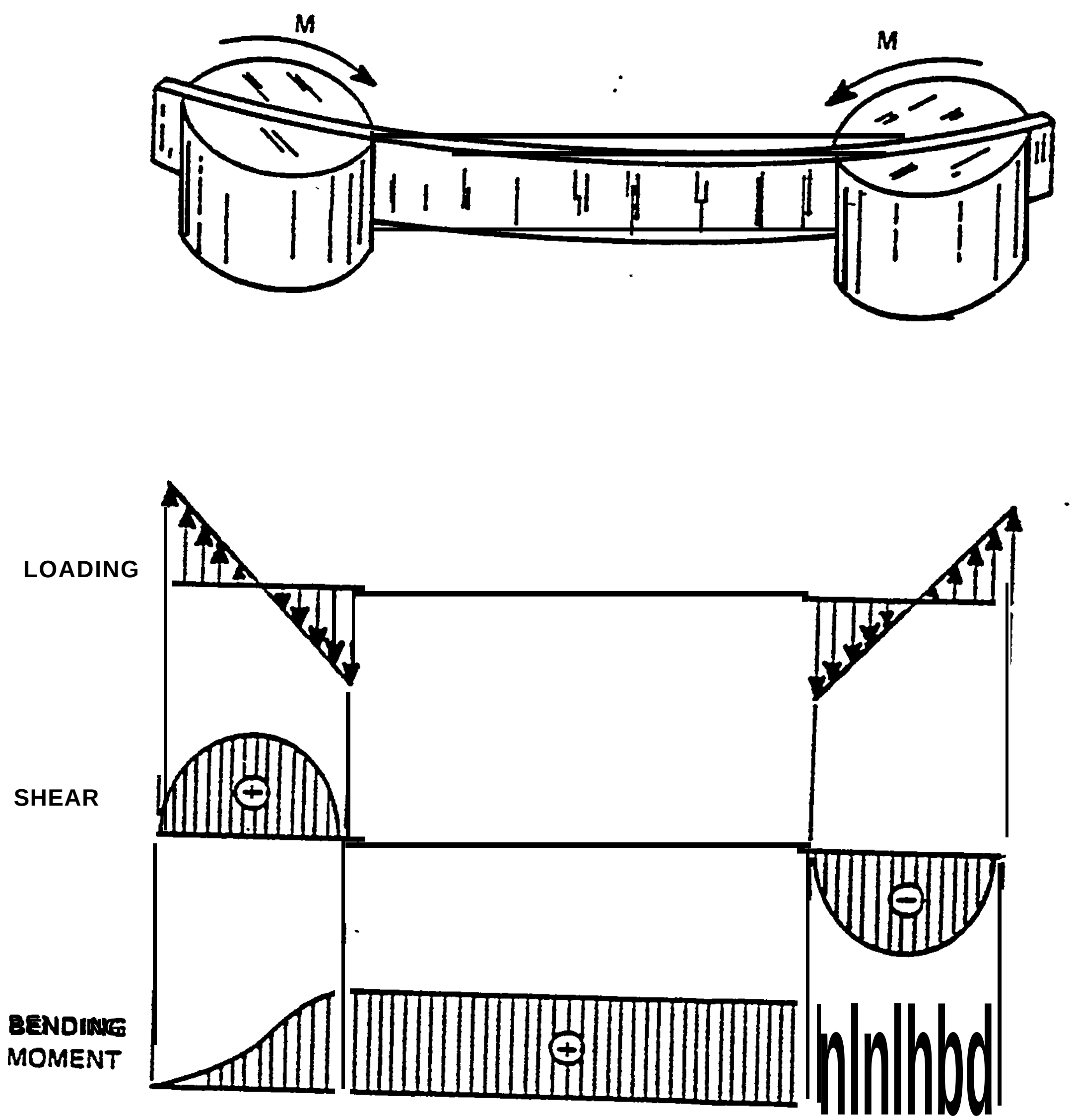


Figure 8. Four-Point Bending



a) Idealized pure bending.



b) Realistic "Pure" bending.

Figure 9. Pure Moment Bending.

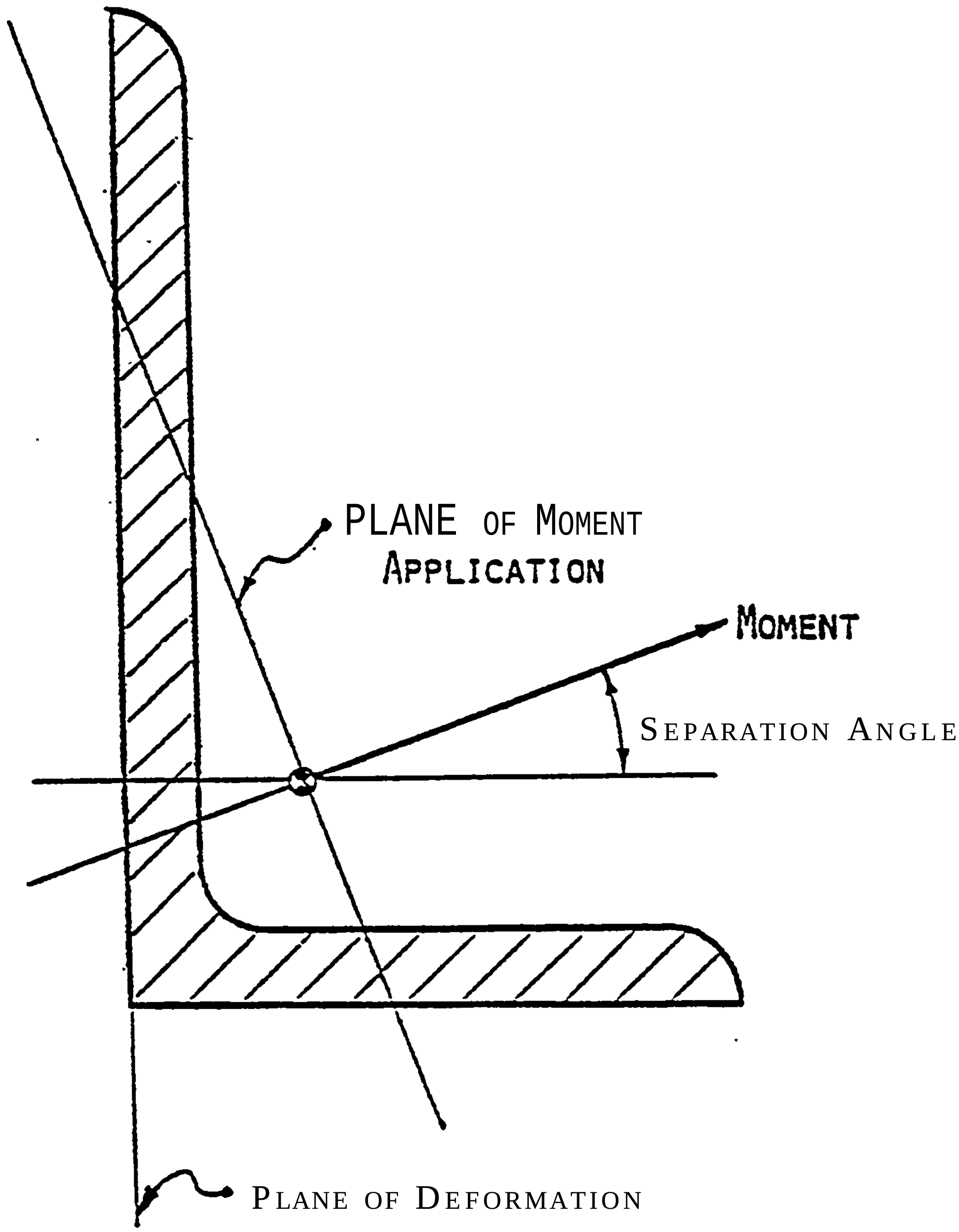


Figure 10. Separation Angle for an Angle *Cross* Section

benders do not have this capability they attempt to minmize out-of-plane deformation to asymmetrical cross section beams by clamping two or more beams together to form a composite member of symmetrical cross section. When unclamped, the forces change after bending, necessitating additional corrective action. This problem is amplified with NASSCO fabricated beams (see Figure 2). The Pullmax-Ursviken frame bender, manufactured in Sweden allows bending in two perpendicular planes so that out-of-plane deformation can be partially removed by a compensating bend; older benders require remounting of the beam (similar to the "Bulldozer") for the restoring bend. Common practice is to ignore it, as with hot slab cooling deformation, and rely on compensation during ship assembly (see Figure 6).

The unique feature of the Case Western bender is its self-adaptive operation, which directs the bending and uses computer controled feedback to continuosuly correct for springback. Out-of-plane deformation could also be corrected by feedback, but this routine appears unnecessary since initial calculations of separation angles have proven adequate to effectively eliminate out-of-plane deformation. An operator can adjust the separation angle manually to correct any incipient out-of-plane deformation; however, such corrections have not been necessary on beams (including a symmetrical) bent in the laboratory.

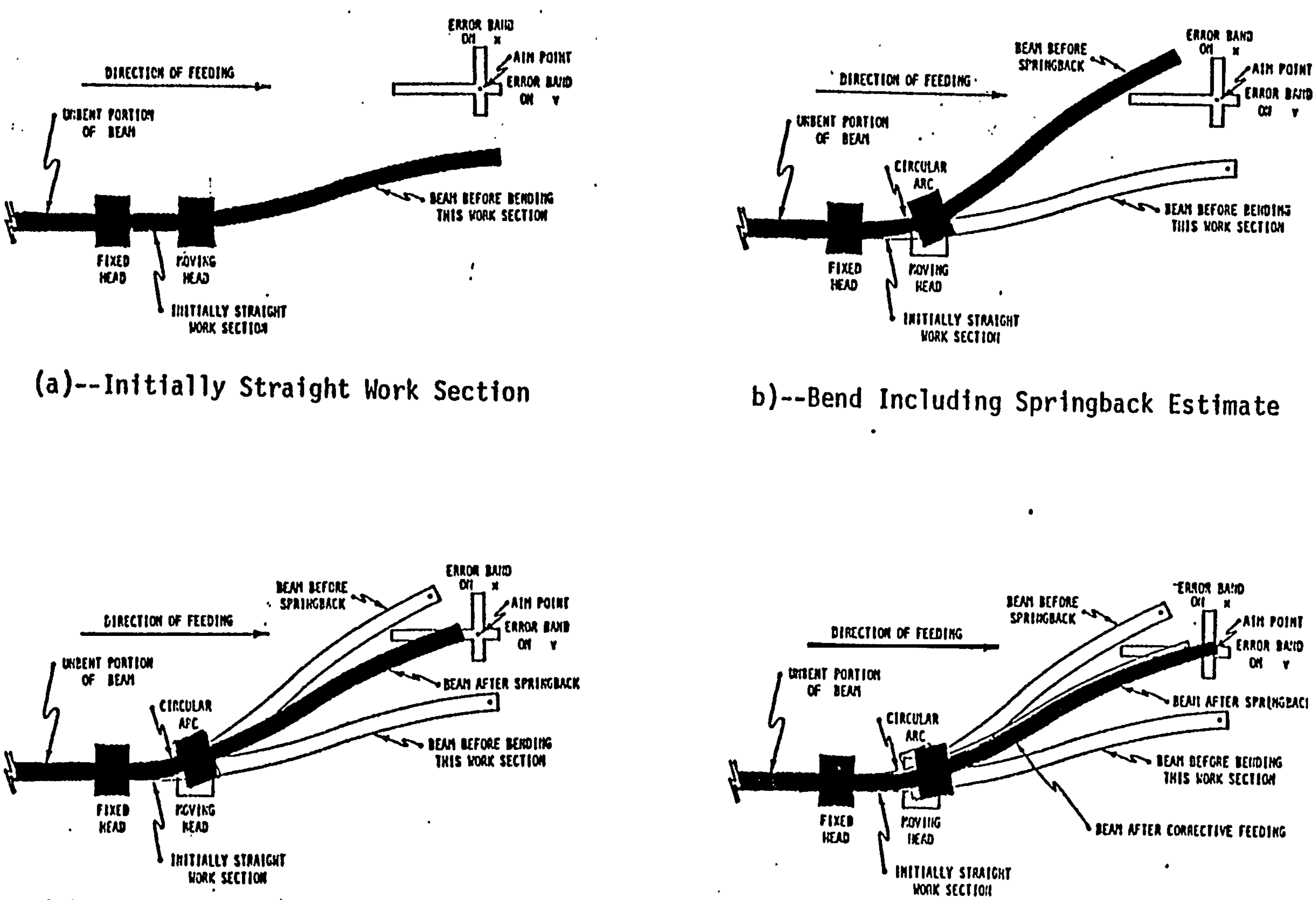
The present computer routines: (1) compute the desired position of the end point of the beam; (2) drive the end point to its proper 'y" coordinate, including a springback correction that is checked after each bend: and (3) once the "y" position is satisfactory, translate the beam end to the desired "x" position.

These actions are summarized in the plan views of Figure 11. The bending moment to any beam is applied by two gripping heads, one of which is fixed and the other of which is movable (the section to the right of the gripping heads of the example has already been bent). All new bending takes place along tie straight section between fixed and moving heads (as in Figure 11A) . Two displacement transducers are mounted on the dot at the end of the beam to read out the (x, y) coordinates of that position. The computer calculates the desired position of the dot after bending--the aim point. The computer then directs an overbend (Figure lIB) and if, after springback, the "y" position is not satisfactory, it may require the calculation of a revised springback correction. This is repeated until the "y" position is satisfactory, at which time the feed mechanism advances the beam to the desired ""x" position.

The result is a machine that incorporates state-of-the art computer technology to upgrade the beam-bending operation to a faster, more accurate process free of many previously unavoidable human errors. Concurrently,the machine employees principles of mechanics made practical by improved electronic control, that produce a structurally superior bend.

DESIGN OBJECTIVE OF THE CNC FRAME BENDER AT NASSCO

The CNC frame bender will be designed for (1) straightening of rolled or fabricated sections to remove distortion due to fabrication or storage and (2) cold bending of frames in a



(a)--Initially Straight Work Section

b)--Bend Including Springback Estimate

(c)--Springback within Error Band on Y

(d)--After Corrective Feeding to Aim Point

Figure 11 --Processing of a Single Work Section

single plane with the flanged section either in tension or compression. The straightening function will be handled by a "canned" program hard-wired in the machine's computer, thus requiring no input data for the straightening of beams. In addition to straightening in the bending (horizontal) planes, the CNC frame bender will also be capable of straightening in the vertical, plane. In addition, a means of correcting for distortion due to twist in the frames will be investigated and, if practical, included in the design of the first CNC frame bender.

The CNC frame bender will handle angle or T-shapes as well as asymmetrical sections up to 25 inches deep having a web thickness up to three quarters of an inch. It will bend the larger frames to a minimum radius of 40 feet; smaller frames, down to approximately 8 inches deep, will be bent to smaller radii. However, the maximum bend (minimum radius) will be kept within the limits of the runout table. The minimum bend radius for 8 inch sections will be 7 feet. The maximum length of the beams will be 42 ft. Overall accuracy objective will be & inch with three iterations.

The production rate of the machine will be a minimum of four (4) 42 ft. long frames per hour and the straightening rate will be eight (8) frames per hour. The frame bender will be designed for minimum operator attention. Ideally, no actions will need to be taken by the operator other than setting up for any particular section, loading the beam, activating the machine, and removing the beam after it has passed. entirely through the frame bender. The machine will conform to reasonable

shipyard safety requirements with electrical equipment suitable for protected outdoor environment.

As currently evisioned, the CNC bending machine's devices and subsystems can be generally listed as follows:

1. A beam feeding device.
2. A fixed head including the clamping and die devices.
3. A stabilization device.
4. A beam marking system. (The extent of marking capability will be determined by practicality and cost).
5. A movable head including the clamping and die devices and main power cylinders.
6. A bending table including pivot mechanism, track and drive system for x-axis movement of the movable head and power cylinder mechanism for the z-axis movement.
7. A runout table including x-y positon indicators and air cushion pedestals with locking and unlocking features.
8. A central hydraulic system including automatic and manual valves and controls.
9. A computer director system including all electrical and electro-hydraulic interface equipment.

PRINCIPLE OF OPERATION OF THE CNC FRAME BENDERAT NASSCO

The beam is fed into the machine through a fixed head containing a die and clamping mechanism, using a variable clamping distance dependent on the size of the beam to be processed and the amount of force required. The feeding-system is to be positioned at the input side of the fixed head, as well as the output side of the movable head so that a new beam can be

automatically moved into the machine and a finished beam completely removed. A pneumatic or hydraulic center punch marking system will be incorporated at the discharge end of the fixed head. If practical the marking system will be capable of transversing along the y-axis so that the end cut of the beam can be punched, as well as suche other reference marks as the water line on transverse beams.

The beam will be fed from the fixed head to a similar movable head with an identical clamping system. If practical, a stabilization system will be included between the fixed and movable heads, clamping the extreme end of the beam web along its length in order to prevent buckling of the beam when the flange is bent to a convex configuration. The distance between the fixed and movable heads will be variable; however, it will be fixed for any one beam or (preferably) for any series of beams. The machine and *the* input data will be designed to allow for the largest possible work section in order to have the highest production rate on the machine. Inflection points will be designed out of the beam model as far as possible by the shipyard's own computer program. Also, full advantage will be taken of any straight sections by keeping them at the ends of the beams to avoid wasting of the ends that must be held by the clamping mechanism.

The movable head will be actuated by two double-acting power cylinders anchored one upstream and one downstream of the movable head. Bending of the beam is accomplished by first clamping the beam with the fixed head, then clamping with the movable head and applying a moment, using the two

power cylinders, to the moving head which has freedom to rotate about a radius from the inside end of the fixed head clamp.

In the case of non-symmetrical sections the out-of-plane distortion will be calculated from the known geometry of the section and automatically compensated for by a third cylinder acting in the vertical direction as described below. The normal procedure for bending is identical to that described in the reports prepared by Case Western Reserve University. The movable head, beam feeding device, marking device, run-out table, and main power cylinders will be mounted on a common rigid base plate. This base plate will be free to pivot about a point in line with the inside end of the fixed head clamp. The vertical power cylinder, mentioned above will be attached to the downstream end of this bed and in the relaxed condition will allow the bed to move either up or down as determined by the out-of-plane deformation of the beam. The compensating force will be applied automatically and concurrently with the bending forces thus assuring that the final bent beam remains in a single flat condition.

During straightening operations, the beam will be fed into the frame bender in an identical manner as previously described and automatically bent to return it to a straight line. At this time, the vertical power cylinder can be used to correct any distortion in the vertical plane.

A run-out table will be provided on the discharge side of the frame bender. The dimensions of the run-out table will be a maximum of 20 ft. wide by 42 ft. to allow bending of the

beam in either direction from the centerline of the bender to a maximum y-axis displacement of 10 feet to either side. The run-out table will consist of a simple frame supporting the mechanism for accurately determining the end position of the beam in the x-y plane. This position indicator will be of the optical, transducer or mechanical linkage type. It will be protected, insofar as possible, from damage that might be caused when removing the beam from the run-out area. The beam will be supported by air casters, the number of casters required being dependent on the length and weight of the beam. These casters will be supported by the run-out table and stacked at the discharge end of the movable head, then will automatically clamp onto the beam at predetermined points. These points will be determined either by the indexing mechanism of the frame bender itself or pre-determined on the input tape. The bearing clamping mechanism, as well as the air bearing supports, will be supplied with service air from the shipyards central system.

Power for the frame bender will be exclusively hydraulic except for the pneumatic power requried for the air casters. A packaged central hydraulic system will belocated on or adjacent to the frame bender and will provide hydraulic power for advancing the beam, adjusting the beam advance mechanism, clamping, stabilizations actuation of the horizontal and vertical power cylinders, and any other necessary functions on the bender. The position indicating equipment will be of the direct electric type.

The computer hardware as well as the interface equipment will be chosen for its adaptability and suitability for the particular function involved; it will also have manual override con-

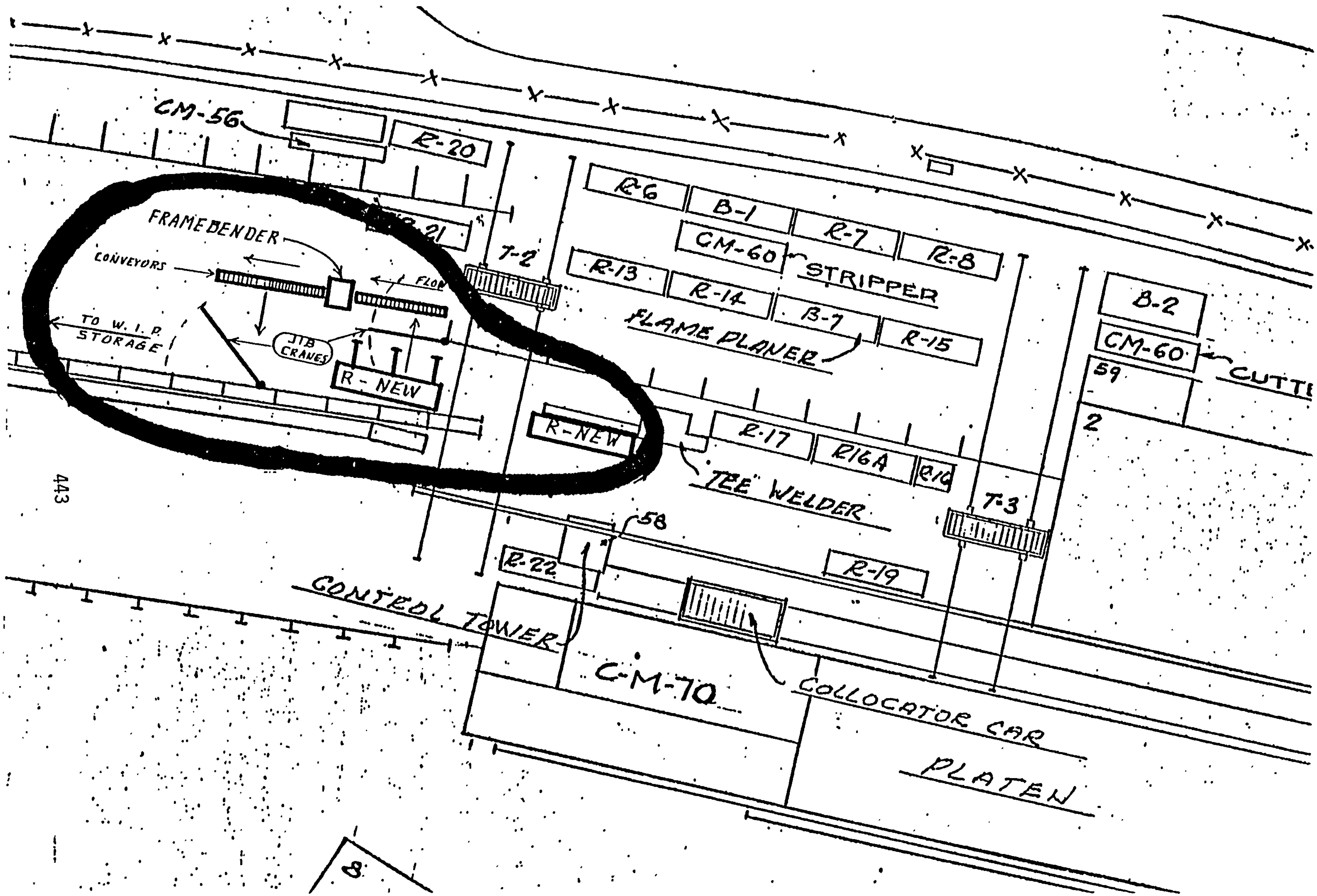
trols so that the operator, if he wishes, may operate any mechanical function of the frame bender.

APPLICATION OF THE CNC FRAME BENDER AT NASSCO

Although the research and development of the CNC frame bender saw use of the AUTOKON program, the production model will have a "stand alone" mini-computer which will permit interface with most of the shipbuilding programs, including SPADES used at RASSCO. SPADES has a frame bending routine that makes template design or inverse curve and locates end cut. This routine will be modified to create paper tapes and incorporate the necessary interface to drive the CNC frame bender. For the purpose of checking and verification, beam design will continue to be produced on the drafting machine; the only change in NASSCO's lofting effort will be the elimination of templates.

The CNC frame bender will be inserted into the production line downstream of the tee beam welder (see Figure 12). The fabricated beams will be accumulated on a roller-conveyor adjacent to the run-off table of the tee beam welder, moved by transfer car (T-2) to another roller conveyor from which they are to be inspected; those beams requiring straightening will be passed through the frame bender and then to work in process (WIP) storage (by size); those beams not requiring straightening will be forwarded directly to WIP storage. As required by production schedules, beams will be withdrawn from WIP storage and routed either directly to the next operation or back to the frame bender for shaping, thence to the next operation. This will permit larger

TENTATIVE LAYOUT
FRAMEBENDER : INSTALLATION



production runs and random access order picking rather than the laborious system of storing and locating beams by individual part numbers or attempting to produce them as they are required. Such improvements in procedure can be made possible *only* because of the automation and production rate associated with the CNC frame bender.

APPENDIX

Reports and Publications

"Automation in Shipyards: First the Frame" (10 rein, 16MM sound color film produced for NSF/RANN by Image Associates, Wash., D.C.)

"Dear Factory: Make 100,000 Widgets," MOSAIC, Vol. 5, No. 4 (Fall 1974), pp. 2-8.

RudY Doornbos, "AUTOKON 71, An Overview," presentation to the 10th annual meeting of the Numerical Control Society New York, April 1973.

Rudy Doornbos, "The AUTOKON System, A Short Survey," Shipping Research Service, Inc., 205 South Whiting Street, Alexandria Va. 22304.

H.w. Mergler, et al., "The Mechanical Development of a Ship Frame Bender in Scale, Part I.," June 1974, extract of thesis of Wieslaw Kosc, NSF Grant GI-35994, Digital Systems Laboratory, School of Engineering, Case Western Reserve University, Cleveland, Ohio 44106.

H.W. Mergler, and D.K. Wright, Semi-Annual Progress Report on An Automated Bending System for the Fabrication of Ship Frames via Self-Adaptive Computer Control, March 1, 1973 to August 31, 1973, NSF Award No. GI-35994, Division of Solid Mechanics, Structures, and Mechanical Design, School of Engineering, Case Western Reserve University, Cleveland, Ohio 44106.

H.W. Mergler, D.K. Wright, T. Kicher, and M. Savage, "Computer Controlled Cold-Forming of Ship Frames," report prepared for the NSF Industrial Automation Conference, Stanford Research Center March 27, 1974, NSF Grant GI-35994, Case Western Reserve University, Cleveland, Ohio 44106.

H.W. Mergler, et al., "Self-Adaptive Computer Control of a Ship Frame Bending Machine, Part II," March 1976, extract of thesis of Donald C. Braun, NSF Grant GI-35994, Digital Systems Laboratory School of Engineering, Case Western Reserve University, Cleveland, Ohio 44106.

D.C. Braun, and H.W. Mergler, "The Case Western Reserve Computer-Controlled Frame Bending Machine,'! paper presented to the EEAPS Technical Symposium, Palm Beach Shores, Florida, June 24-25, 1975.

H.W. Mergler, D.K. Wright, D.C. Braun and A.D. Gresler, "Computer Controlled Ship Frame Bending Machine," Third NSF/RANN Grantees Conference on Production Research and Industrial Automation, Oct. 1975, Case Western Reserve University, pp. 9-21.

Research Triangle Institute N.C. "Rann Utilization Experience, Automated Bending System For The Fabrication Of Ship Frames (Update of Case Study No. 5)", Case Western Reserve University.

SPECIAL INTEREST GROUP REPORTS

INTERACTIVE GRAPHICS FOR LOFTING AND DRAFTING

Douglas J. Martin

PRODUCTION CONTROL SYSTEMS

John C. Williams

PIPE DETAILING AND FABRICATION SYSTEMS

George P. Putnam

IIT Research Institute
Chicago, Illinois

INTERACTIVE GRAPHICS FOR LOFTING AND DRAFTING

This session centered on the current capabilities of several commercially available graphics systems in parts nesting and computer aided shipyard drafting. Three representatives of graphics system vendors participated on a panel to answer questions from the audience concerning their products' capabilities and graphics systems in general. These representatives were Dr. Robert Cowen of Computervision Corporation, Robert N. Hickox of Adage, Inc. and Lou Melancon of Auto-Trol Corporation. In addition, a representative of the Italian yard Italcantieri S.p.A. was on hand to relate that yard's experience in the use of Adage equipment for interactive nesting.

Of interactive nesting Italcantieri, in response to questions from the floor, has seen a reduction in nesting labor as a result of using their system from between 20,000 to 24,000 man-hours per year to 2000 man-hours per year. He further stated this effort represented the production of some 2500 nest tapes.

On the topic of system reliability the vendors reported uptimes for their systems in excess of 95%. The cost of these systems was also questioned. Without a clear description of the application, number of users, etc. of such a system, the vendors were able to respond only that the costs ranged from around $100,000 for a single user drafting system on up.

On the topic of computer aided design systems two members of the audience reported on the Navy's development efforts in this area. Two current applica-- tions cited in the Navy are a computer aided hull lines generation system employing interactive graphics and a graphics assisted ship's arrangements program.

PRODUCTION CONTROL SYSTEMS

This special interest group meeting was attended by 35-40 REAPS symposium participants. It was a free form meeting, and the direction of the discussion was provided entirely by the group. As a consequence, it delved into many areas that, by definition, were not truly production control systems. However, it brought out some very significant information related to production control systems for shipyards.

The initial discussion concerned the use of generalized production control systems. This discussion concluded that every shipyard is unique and has its own requirements for production control. The yard with 4000 employees has significantly different requirements than the yard with 500 employees. It was, therefore, concluded that every yard needs its own individual system.

Subsequent discussions centered on how a system should be designed. Currently, most systems are designed from the top or middle down. As a result, the system does an adequate job of satisfying middle and top organizational requirements. However, quite frequently it fails to address the needs of the man in the yard. Consequently, it was emphasized that a good system should be designed from the bottom up to maximize the information needed by the man in the yard. It was further pointed out that the system should maximize the use of the available resources. This point created some intense discussion on whether a system should maximize the use of available resources or control the amount of resources to be available. The group generally agreed that this would be a very desirable objective but difficult to achieve. To do this, it is imperative that the system be creditable and reliable to the yard man. Currently, budget estimates are sufficiently unreliable so that the yard man ''hedges his bet" by over estimating on the amount of resources required. It was noted that the process of designing a production control system is designing a change-in the way someone does his work. Consequently, you must give him a more reliable tool or he will continue to use his current tools which are time proven.

At this point the interest group made a very emphatic point. Production control systems demand good valid data as input or they are worthless. Judging

from the ensuing discussion current shipyard budget estimates do not provide reliable input data.

There was significant discussion concerning the responsibility for unreliable budget estimates. This was a relatively inconclusive discussion, however everyone did seem to agree that budget reliability has to start in the design process. In discussing the design problem the group made the following points:

The designer must know everything that went before to preclude re-inventing end cuts, brackets, etc. everytime one is needed.

Design drawings are prepared on a stem to stern basis not in modular form as the ship is built. The interpretation of these drawings is too frequently left to the yard man which further wastes his time and delays construction.

Bills of material are also prepared on a stem to stern basis with the same problems.

Desiqns must be prepared to satisfy the moduction practices of six or seven different shipyards each with their own individual preferences.

There was subsequent discussion on why these problems exist and how they might be alleviated:

Design agents are too far removed from the yards; they need to be much closer.

Yards should prepare their own detail drawings and bills of material to reflect internal practices to the maximum extent possible.

Yards should conduct production engineering reviews of every drawing before it goes to the yard.

Design agents have an entirely different set of problems from the yards, primarily in the area of time and cost.

In summary the following overall conclusions were reached:

Production control systems must be unique for every yard.

Production control systems demand reliable input.

Other system improvements are needed first:

- Budget reliability, production engineering reviews, and detail drawings consistent with yard practices.

Yards need the methodology to take advantage of similarities in their products.

- Every ship a yard builds is different, however there are significant similarities at the component level.

PIPE DETAILING AND FABRICATION SYSTEMS

The proposed plan to be conducted within the REAPS program met with general acceptance. However, some comments seem pertinent:

- The scheduling system should be developed to balance:
  - the optimization of tool and equipment utilization
  - the maximization of production throughput with minimum work-in-process inventory.
- At least one European system provides for storing 200 programs at the machine to facilitate solving the above problem.
- It is planned to handle all pipe sizes and materials within the proposed facility:
  - different processing lines will be set up for different sizes
  - within each size range all materials will be handled on the same processing line.
- The-development should take place module by module (i.e., racking, blast and painting, etc.) so that those modules with the largest potential pay-offs can be implemented first, and each yard can apply those modules or combinations of modules having the most cost appeal to it.

OTHER REMARKS

1) The current analysis calls for a 2-5 million dollar investment with a "less than five year" payback.

2) The blast and paint module appears to have a one year or less payback.

3) Some of the savings are independent of automating the pipe fabrication, for example, 60% of the welding can be converted from stick to wire.

4) Maximum advantage should be taken of related Navy developments.

The Newport News Pipe Detailing project is nearing completion. The next step appears to be to continue development at either the production or design end. The developer suggests the production end involving the feeding of pipe

geometry into a production control system and/or an inventory control system. At the design end the ground work has been laid for developing a system which permits designing from sketches and bypassing the manual drafting step.

There were several cormnents indicating that automated drafting packages are available and very cost effective.

Two major needs in systems were identified:

1. There is a need to perform dimensional checking (for example, does the pipe size match the flange size?). Currently, available systems deal with symbols, not dimensions.

2. Data base management systems need to be considered when examining software portability. (Portability is as much a factor as programing language.)

The system payback appears very short. Estimates ranged from less than a year to 18 months. In addition, 80% of the benefits may result from implementing 50% of a system. Therefore, care should be taken to avoid implementing any portions of a system that are not cost effective.

APPENDIX A

AGENDA

TUESDAY, JUNE 21

l o o -$100 REGISTRATION — ST. MAXENT FOYER, 8th FLOOR

5,45 GENERAL SESSION — ST. MAXENT A

WELCOME
J. J. GAweY. MahRbne Adminlstratlon U.S. Department of commerce

THE REAPS PROGRAME – PROGRESS AND PROSPECTS
D. J. MARLiN, NT Reserch institue

N/C JUSTIFICATION IN THE SHIPYARD
C. french Both iron Work.

1o,oo INFORMAL DiSCUSSION PERiOD

10:10 GENERAL SESSION — ST. MAXENT A

A LOW COST PARTS DEFINITION SYSTEM
A. F. KAun, NewPORT News Shipbuildlng & Dry Dock Co.

COMPUTR .AIDED ENGINEERING AND DRAFTING IN SHIP. BUILDING
R. Cower. C.mputer vldon Corporation

INTERACTIVE GRAPHICS AS A TOOL FOR COMPLETE HULL AND PARTITION DESIGN
R. N. HICkox, Adwe, Inc.

12.1O L U N H

1.45 Parallel Sessions

SESSION 1 ST. MAXENT A

USER REQUIREMENTS FOR THE NEWPORT NEWS PIPE DETAILING SYSTEM
P. W. Rourke and P. J. Kelly, NewPORT News Shipbuilding & Dry Dock Co.

HIERARCHICAL APPLICATION OF COMPUTERS FOR AN AUTOMATED PIPE SHOP
H. AYa. MIIMI1 Engeineearing & Shipbuilding Co., Ltd.

CONSIDERATIONS FOR AN AUTOMATED PIPE FABRICATION FACILITY
O. GaUin. Avondele Shipyard Inc.

SESSION 2 ST. MAXENT C

A SHIPYARD LABOR CONTROL SY STEM
L. Deochemp, SPAR Associations

THE INGAALLS PRODUCTION, PLANNING AND CONTROL SYSTEM
J. F. Davldeon, tngello Shipbuildlng Dlv.. Litton Industries,

SPCS -- A COMPRENSIVE SYSTEM FOR SHIPYARD PRODUCTION CONTROL
A. W. Adan and R. Smlth
A&P Appledore. Ltd.

1:1O INFORMAL DISCUSSION PERIOD

4,00 ● PARALLEL SPECIAL INTEREST GROUP MEEDING

SESSION 1 ST. MAXSENT A

INTERACTIVE GRAPNICS FOR LOFTING AND DRAFTING

SESSION 2 ST. MAXENT C

PRODUCTION CONTROL SYSTEMS

SESSION 1 PRESIDENTS ROOM

PIPE DETAILING AND FABRICATION SYSTEMS

5.15 - 4.30 RECEPTION — KEITH TEMPLE ROOM
Sponsored by NT Reseuch Institue

WEDNESDAY, JUNE 22

1.00 - 1.30 REGISTRATION — ST. MAXENT FOYER, 8th FLOOR

1.41 PARALLEL SESSIONS

SESSION 1 ST. MAXENT A

HIGHLIGHTS OF THE 1977 AUTOKON USERS CLUB MEETING
J. F. Mack, Aker Group

SPADES' PROORESS IN U.S. SHIPBUILDING
V. H. Nueeo, Avondale Shipyards Inc.

ONLINE DATA ENTRY AT PORT WELLER
J. Hukey. Port Weller Dry Docks

SESSION 2 ST, MAXENT C

THF BETHLEHEM DAMAGED STABILITY PROGRAM
F. J. SLYKER and B.G. Boht, Bethlehem Steel Shipbullding

SPADES' AS AN AID IN Ship DESIGN
J. Ulteecn. Call and Auoclatea

I0.00 INFORMAL DISCUSSION PERIOD

10.30 PARALLEL SESSIONS

SESSION 1 ST. MAXENT A

USER. ORIENTED GUIDE FOR THE AUTOKON NORMS
J. F. MACK. Aker Group

NEW FEATURES FOR REAPS AUTOKON
P. D. Taske, iiT Reserch institue.

USER EXPERIENCE WiTH REAPS SIMPLIFIED ALKON
B. J. Breen General Dynamlcs Corporation

SESSION 2 ST. MAXENT C

GROUP TECNOLOGY AS RELATED TO THE SHIPBUILDING INDUSTRY
1. Hem, POnnoylvonla State University

THE SFI CODING AND CLASSIFICATION SYSTEM FOR SHIP INFORMATION
F. MeCnnOii and A. ManchLmt, Shipplng Reserch service, Inc.

12.15

1.30 PARALLEL SESSIONS

SESSION 1 sT. MAXENT A

SOME USEFUL NASA TECNNOLOOY FOR THE SHIPBUILDING INDUSTRY
J. D. Meyer, NT Reserch Intltue

NOW SMALLER SHIPYARDS ARE PROFITING THROUGH N/C
D. Rox. Call and Auoclate,

COMPUTER AIDED SHIP DESIGN AND CONSTRUCTION IN THE NAVY
T. Corin.. Naval Ship Research end Development Center

SESSION 2 ST. MAXENT C

RECENT DEVELOPMENT IN COMPUTER. BASED SYSTSMS AT KOCKUMS
K. HOlmeren. Kockums Computer Systems AB

3.00 INFORMAL DISCUSSION PERIOD

3.10 GENERAL SESSION — ST. MAXENT A

APPLICATIONS OF WATER JET TECNNOLOGY TO SHIPBUILDING
T.J. LABOUR, IIT Research Institue.

THE APPLICATION OF A CNC FRAME BENDER WITHIN AN AUTOMATED SHIPYARD
J. Acton, NASSC0 and T. Mackey, Hyd. Products, Inc.

SPECIAL INTEREST GROUP REPORTS

INTERACTIVE GRAPHICS FOR LOFTINO AND DRAFING
D. J. Martin*

PRODUCTION CONTROL SYSTEMS
J. C. Williame

PIPE DETAILING AND FABRICATION SYSTEMS
G. P. Putnam.

IIT Rersearch Institue.

5.00 ADJOURNMENT

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